

Evaluating and Integrating Educational Technology
in the Elementary Mathematics Classroom

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Abstract

This study used a meta-analysis to analyze several studies examining the impact of technology in the mathematics classroom in order to investigate the functionality of digital tools, and the integration of those digital tools, that most positively impact student achievement and student engagement. Through a keyword search and exclusion criteria, a systematic collection of relevant articles was compiled and analyzed through a two-tier coding scheme. The analysis determined that professional development opportunities need to be provided before, during, and after integration of technology. In addition, educators and students need time prior to the lesson or unit to become familiar with the digital tool and its available functions. Furthermore, educators need to put pedagogy first in order to align strategies with the appropriate digital tools. Finally, digital tools should be introduced in a blended format, with the teacher as a facilitator and the digital activities connected to the curriculum.

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CHAPTER ONE: INTRODUCTION TO THE STUDY

For the 2015 – 2016 school year, the Toronto District School Board (TDSB) allocated three million dollars towards the use of technology in the classroom (Toronto District School Board, 2015). This number has been on the rise in the past several years due to researchers linking the use of technology to higher student achievement and engagement. For example, after performing a second order meta-analysis on 25 studies including 1,055 primary studies, Tamim (2011) found that the average student in a technology-enhanced classroom performed 12 percentile points higher than the average student in traditional classroom settings. However, some studies examining the impact of technology are finding the use of technology to have a negative or null effect on student achievement (Carr, 2012; Carrasco & Torrecilla, 2012).

This study will examine the functionality of digital tools and the different qualities of technology integration to determine which factors maximize the technology's potential impact on student achievement and student engagement. This chapter will describe the problem, the purpose of the study, the study rationale and the theoretical framework, in addition to outlining the rest of the document.

The Problem

Teaching mathematics with technology is a complex process that requires educators to be knowledgeable in a large number of competencies (Bennison & Goos, 2010; Jarvis, 2016; NCTM, 2015; Thomas & Hong, 2012). Thomas and Hong (2012) state that the teacher's environment, attitude, confidence, and ability all affect their decision to use technology to teach mathematics. A teacher needs to develop their pedagogical technological knowledge, which includes the principles and techniques required to integrate technology into mathematics classrooms, in order for the use of

technology to be effective. To accomplish this, educators need to have an understanding of how to use technology within a classroom, have a strong understanding of how to teach mathematics, value the use of technology, and build their confidence with using technology in mathematics.

However, many of the professional development opportunities offered to teachers regarding the use of technology take on a *show-and-tell* structure that focuses on specific products and their functionality, rather than being workshops which develop teachers' pedagogical knowledge (Bennison & Goos, 2010). This lack of knowledge leads to educators forcing technology into traditional teacher-focused instructional methods, resulting in the ineffective integration of educational technology and technology enhanced non-learning (Kinchin, 2012).

Purpose of the Study

The purpose of this study is to deconstruct articles that examine the effect of technology on student achievement and engagement in elementary mathematics in order to determine the functions of digital tools and the qualities of technology integration that most impact student learning. In order to accomplish this, a meta-analysis of studies examining the impact of technology on the engagement and achievement of mathematics students aged 10 to 14 years will be conducted. The meta-analysis will aim to answer the following questions:

- 1) How do the qualities of the educational technology integration effect the digital tool's impact on student achievement and engagement?
- 2) How does the functionality of the digital tool used affect its impact on student achievement and engagement?
- 3) What is the most effective way to evaluate and integrate technology to most positively impact student achievement and engagement?

Study Rationale

This study aims to provide a resource for educators to help guide them in effectively evaluating and integrating educational technology into their mathematics classrooms. This resource will help educators increase the potential impact of technology on student achievement and engagement. Thus, not only will this study serve as a resource for educators, but it could have a positive impact on student learning. In addition, this study can help inform the need for an increase in the number of professional development opportunities that are available to educators, and will encourage educational technology companies to design products that have the potential to positively impact student achievement and engagement.

Theoretical Framework

In this section, I will explore two frameworks that are commonly referred to when evaluating or integrating educational technology.

The TPACK Framework

Developed by Dr. Punya Mishra and Dr. Matthew Koehler, the TPACK Framework (see Figure 1.1) outlines three primary forms of knowledge – *content knowledge*, *pedagogical knowledge*, and *technological knowledge* – along with how these three types of knowledge intersect in order to construct the technological pedagogical content knowledge an educator needs to effectively teach with technology (Koehler & Mishra, 2008).

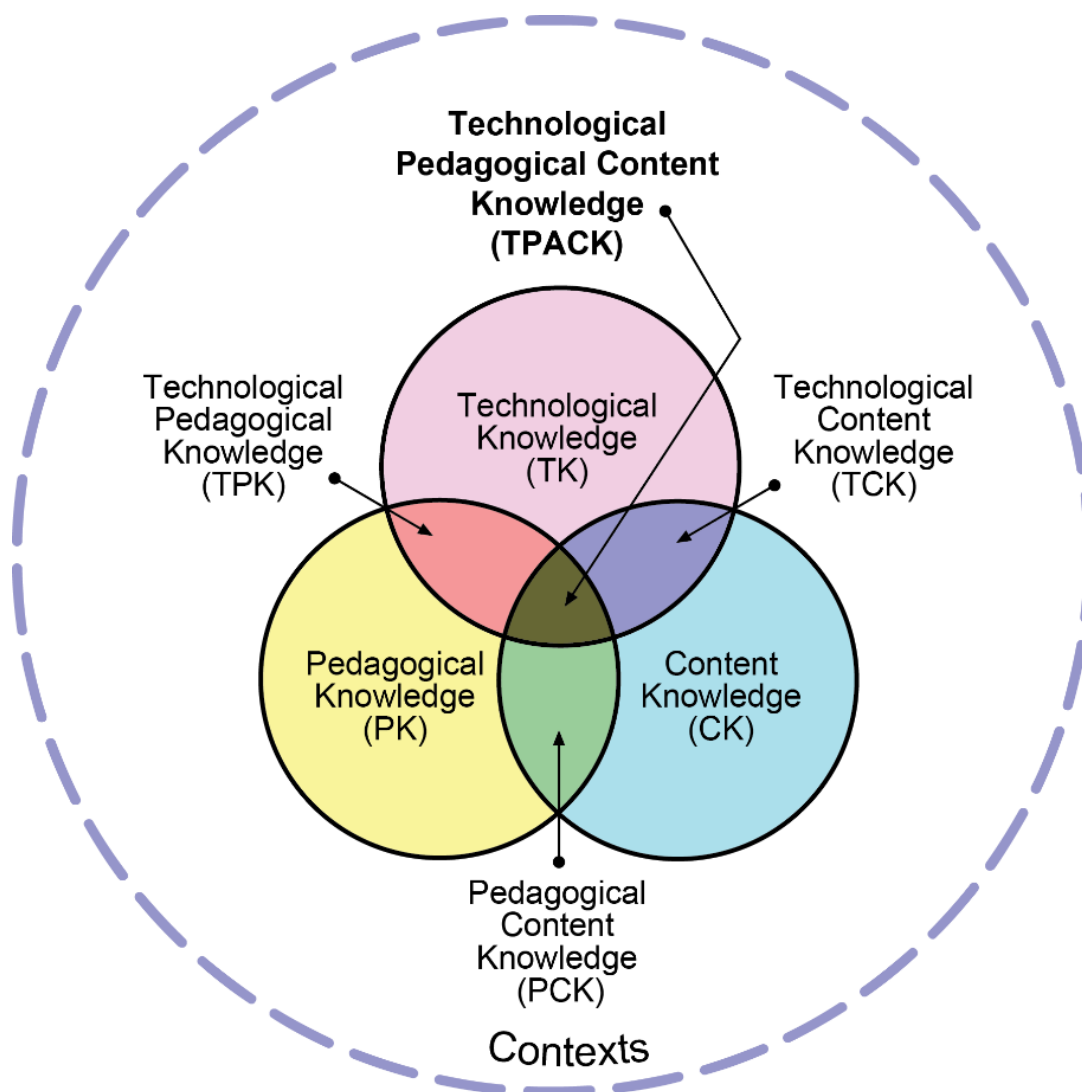


Figure 1.1. TPACK Framework. This figure illustrates the TPACK Framework reproduced by permission of the publisher, © 2012 by tpack.org

According to Koehler and Mishra (2008), *content knowledge* includes the knowledge of concepts, theories, ideas, and procedures within a given field. Without this, students could receive incorrect information and develop misconceptions.

Pedagogical knowledge is the knowledge of the process and methods of teaching and learning, such as understanding student learning, classroom management, effective lesson planning, and accurate, informative assessment and evaluation. Pedagogical knowledge allows educators to understand how students construct knowledge and how learning theories apply to individual student needs. Combining these two areas into *pedagogical content knowledge* (PCK) provides educators with the knowledge and skills they need to effectively apply different teaching strategies and learning theories to help students learn within a particular field or across fields.

Technological pedagogical content knowledge (TPACK) is the combination of content knowledge, pedagogical knowledge, and knowledge of the use of technology in order to effectively learn and teach with technology (Koehler & Mishra, 2008). This includes the understanding of how best to represent concepts using technology, pedagogical strategies that can be enhanced using technology, knowledge of what concepts are more difficult to learn and how they can be addressed more effectively using technology, understanding of students' prior knowledge, and knowledge of how to use this technology constructively.

In the context of mathematics, Guerrero (2010) explains that an educator's TPACK is the knowledge of how to use technology to support teaching and learning mathematics, including the educator's beliefs about mathematics, how mathematics can be addressed through the use of technology, and which concepts are important for students to learn through the use of technology. Educators must decide how to use technology to meet the needs of individual students, the content, and instruction, in

addition to deciding which digital tool would accomplish this most efficiently. For example, if a teacher was to use an interactive whiteboard in a lesson teaching a mental addition strategy, the mathematics educator would have used their knowledge of the mathematics strategy, their pedagogical content knowledge of the teaching methods that would be most appropriate to facilitate developing this mental skill, and their knowledge of using interactive whiteboards to effectively teach the mathematics concept (Muir, Callingham, & Beswick, 2016).

The SAMR Model

Developed by Dr. Ruben Puentedura, the SAMR Model (see Figure 1.2) defined the different levels of technology tools and their use within the classroom in order to encourage educators to enhance the quality of technology use (Green, 2014; Romrell, Kidder, & Wood, 2014).

According to Romrell, Kidder & Wood (2014), *substitution* is the use of technology as a substitute for learning activities without adding any functional change. For example, students could be asked to listen to a podcast to review a lesson or participate in an online discussion. *Augmentation* is the use of technology as a substitution tool with some functional improvement, such as using text messaging to help students learn vocabulary or using video and audio to reference material in context (Romrell, Kidder, & Wood, 2014).

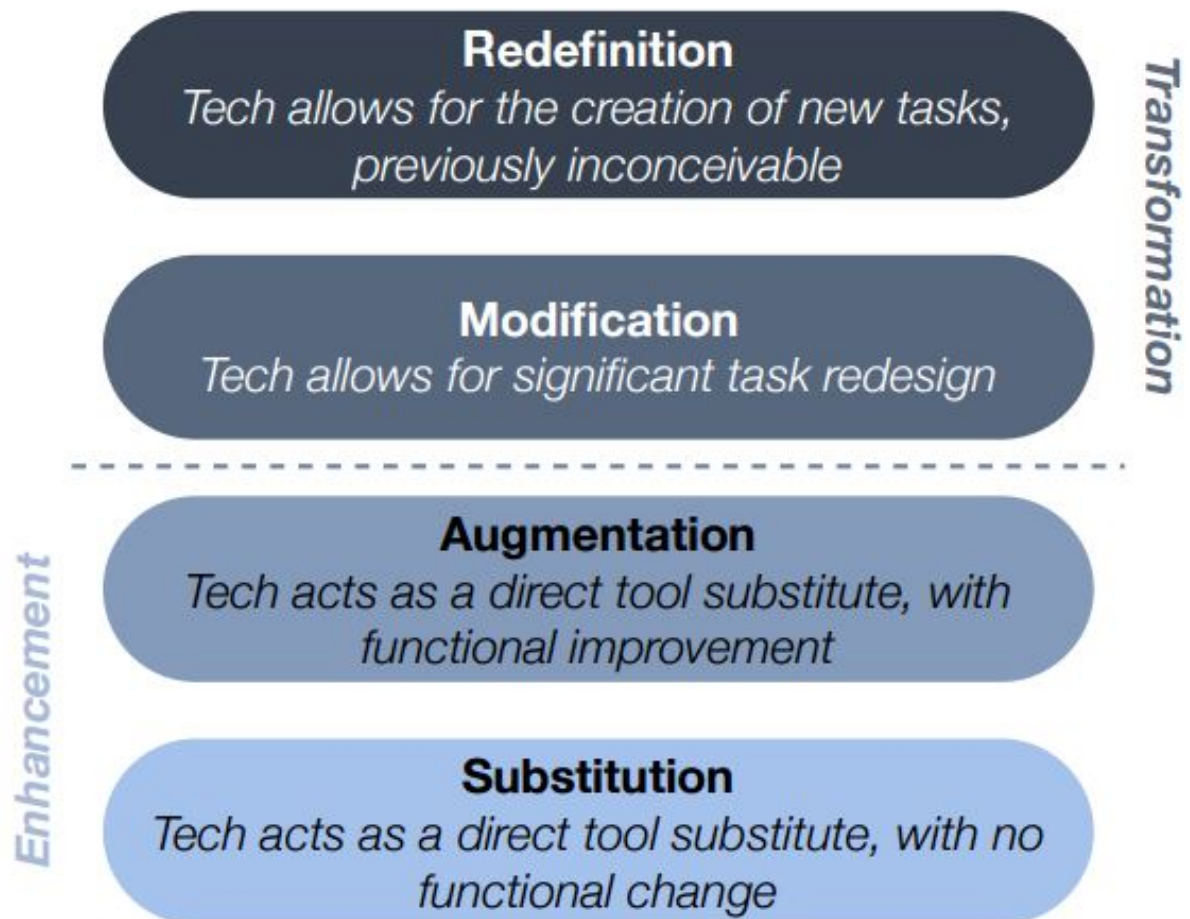


Figure 1.2. The SAMR Model. This figure illustrates the SAMR Model from Puentedura, R. (2014). Frameworks for educational technology: SAMR, the EdTech Quintet, and the Horizon Report.

According to Romrell, Kidder & Wood (2014), the third level in the SAMR Model is *modification*, which is the use of technology to redesign learning activities. For example, text messaging can be used to send students updates on the events in a simulated flood disaster. After each message, students could decide whether to start flood alert procedures or not, and responded with their decision via text message. The next message depended on the previous message; this allowed the simulation to be redesigned, and provided the opportunity for students to participate in real-time decision making. Lastly, *redefinition* is the use of technology to create a task that could not have been done without the use of the digital tool. For example, an application was developed to help Chinese students learn English by using GPS to find the student's location. English descriptions of the objects and places around the student would then be displayed over the image seen through their phone's camera. This type of activity would not be possible without the use of the phone's camera and GPS. Using tools within the substitution and augmentation categories can enhance learning, whereas using digital tools within the modification or redefinition categories has the potential to transform the learning experience (Romrell, Kidder & Wood, 2014).

Scope and Limitations of the Study

Teaching with technology is a complex process that requires educators to be knowledgeable in a large number of competencies such as content knowledge, pedagogical knowledge, and knowledge of the use of technology in order to redefine the learning experience to most benefit student learning (Bennison & Goos, 2010; Jarvis, 2016; Koehler & Mishra, 2008; NCTM, 2015; Romrell, Kidder & Wood, 2014; Thomas & Hong, 2012). Therefore, it is important to narrow the focus of this

study to specific content knowledge and a particular pedagogical focus. Thus, this study will focus on elementary mathematics pedagogy and content.

Furthermore, the analysis of the qualities of technology integration and functionality of the digital tools are limited by the description presented within the study. Although studies with insufficient information are filtered out by exclusion criteria within the coding stage, this may result in a smaller number of valuable articles. Additionally, aspects of functionality or qualities of integration may have been present in the study but not reported in the research paper. Lastly, Card and Little (2012) state that studies which result in null or insignificant findings tend to not be published, thus resulting in a publication bias.

Document Outline

The next chapter will provide a review of the relevant literature associated with this study in order to provide a background of the research already produced in this area. Chapter Three will then go into detail on the methodology of this study, including how the data was collected, how the data was analysed, the assumptions and limitations of the study, and the validity and reliability of this study. Chapter Four will then present the findings of the study, followed by Chapter Five, which will discuss the findings, provide recommendations, and conclude the document.

CHAPTER TWO: REVIEW OF THE RELATED LITERATURE

This chapter outlines the relevant literature that forms the background to this study. The first section discusses the current best teaching practices and pedagogy in elementary mathematics education. Second, this chapter will examine how technology may enhance these practices. The third section will examine the link between student engagement and student achievement. The fourth section discusses evaluating technology, and section five finishes off the chapter by discussing technology integration.

Best Practices in Elementary Mathematics Education

The *Ontario Curriculum, Grades 1 – 8: Mathematics* (Ontario Ministry of Education, 2005) argues that today's students need to be able to, "think critically about complex issues, analyze and adapt to new situations, solve problems of various kinds, and communicate their thinking effectively" (p. 3) in order to succeed in an information and technology-based society. Through elementary mathematics education, students develop their ability to problem solve, reason, justify conclusions, express their ideas clearly, and apply their knowledge to the real world.

The Ontario Ministry of Education (2005) outlines seven processes through which students develop and apply mathematics knowledge and skills. *Problem-solving* is essential to learning mathematics. By learning through problem-solving, students can connect mathematical ideas and develop conceptual understanding. George Polya's four-step model (see Figure 2.1) helps students to think critically about a problem and the process through which to solve it. First, a student must understand the problem and identify the given information and the information needed to solve the problem. Second, students must make a plan by considering possible strategies or a combination of skills. Third, students carry out their plan using

effective communication skills, and finally, students must reflect on their solution to ensure their answer is reasonable and that they answered the question fully.

Small (2012) states that when students learn through problem-solving using an authentic, interesting problem with a real-world context, they develop a deeper understanding of the mathematics concepts, they are more motivated and self-confident, and they become more independent in their learning. To help students develop problem-solving skills, educators can have students act out the problem, use models or manipulatives, draw pictures, guess and test, look for patterns, and use charts, graphs, or lists (Small, 2012).

The process of *reasoning and proving* helps students develop a deeper understanding of math concepts through exploring and developing ideas, and justifying results (Ontario Ministry of Education, 2005). Through this process, students learn to make inferences, generalize, verify, and develop logical reasoning skills (Small, 2012). Students can also use conjectures to practice reasoning and proving. Small (2012) defined conjectures as a statement that has not yet been proven to be true or shown to be false. Educators can model this process by thinking out loud and by asking meaningful questions such as “Why do you think this happened?” and “Will this always happen?” (Small, 2012).

The process of *reflection* helps problem-solvers to monitor their own thought processes, make conscious decisions, strategize, and make sense of problems (Ontario Ministry of Education, 2005). Educators can use questioning to help students reflect on mathematical processes, and can also leverage class discussions so that students can listen to others’ ideas and compare them to their own (Small, 2012).

| Understand the Problem (the exploratory stage) |
|--|
| <ul style="list-style-type: none"> ➤ reread and restate the problem ➤ identify the information given and the information that needs to be determined <p>Communication: talk about the problem to understand it better</p> |
| Make a Plan |
| <ul style="list-style-type: none"> ➤ relate the problem to similar problems solved in the past ➤ consider possible strategies ➤ select a strategy or a combination of strategies <p>Communication: discuss ideas with others to clarify which strategy or strategies would work best</p> |
| Carry Out the Plan |
| <ul style="list-style-type: none"> ➤ execute the chosen strategy ➤ do the necessary calculations ➤ monitor success ➤ revise or apply different strategies as necessary <p>Communication:</p> <ul style="list-style-type: none"> ➤ draw pictures; use manipulatives to represent interim results ➤ use words and symbols to represent the steps in carrying out the plan or doing the calculations ➤ share results of computer or calculator operations |
| Look Back at the Solution |
| <ul style="list-style-type: none"> ➤ check the reasonableness of the answer ➤ review the method used: Did it make sense? Is there a better way to approach the problem? ➤ consider extensions or variations <p>Communication: describe how the solution was reached, using the most suitable format, and explain the solution</p> |

Figure 2.1. George Polya's Four-Step Model. This figure illustrates the steps taken to effectively solve a problem from the Ontario Ministry of Education Mathematics Curriculum (2005, p. 13).

The process of *selecting tools and computational strategies* is important in order for students to develop their ability to select the appropriate tools, manipulatives, and strategies in order to successfully complete tasks and solve problems (Ontario Ministry of Education, 2005). Manipulatives such as base ten blocks, counters, fraction bars, connecting cubes, coins, and spinners can be used to develop concrete representations of mathematical ideas (Small, 2012).

The process of *connecting* mathematical ideas helps students to relate concepts to each other, showing that mathematical concepts are not isolated ideas but rather can be used together to deepen their understanding of all strands (Ontario Ministry of Education, 2005). Educators can help students make connections through studying problems in the context of the real world or fantasy worlds (Small, 2012). Additionally, cross-curricular situations can help students develop their own process of solving problems and make their own connections, which deepens understanding.

The process of *representing* is extremely important, as it allows students to represent mathematics ideas and relationships as well as develop their communication skills and their ability to justify their answers (Ontario Ministry of Education, 2005). The more adaptive students are in finding alternative ways to represent mathematical ideas, the more likely they are to develop a deep understanding of a concept (Small, 2012). Educators can encourage students to represent answers in various ways through questioning and exploration with manipulatives.

Finally, the Ontario Ministry of Education (2005) explains that the process of communicating and expressing mathematical ideas orally, visually, internally, and in writing is essential in connecting all the processes together and in addressing misconceptions. It is important for educators and students to understand that problems can be solved in many different ways, and thus, effective communication skills are

necessary in order for students to clarify their ideas and thought processes (Ontario Ministry of Education, 2005). Small (2012) explained that educators can help students develop oral communication through peer discussion, mixed ability grouping, giving time to think and develop a response, reflecting on communication skills, encouraging listening, and prompting students. Giving predictions, comparing approaches, and using manipulatives can also provide opportunities for oral communication. Educators can help students develop written communication skills through personal and descriptive writing, explanatory writing, and math journals. Questioning, scaffolding, and exemplars can also help students develop effective written communication skills. Lastly, ensuring students feel safe, respected, and supported within the classroom can help students feel comfortable speaking, responding, and elaborating within the mathematics classroom (Jarvis, 2016; Ontario Ministry of Education, 2005).

The Ontario Ministry of Education (2006) published *A Guide to Effective Instruction in Mathematics, Kindergarten to Grade 6* in which they described three instructional approaches to support students in learning mathematics. *Shared mathematics* is an instructional approach where students work collaboratively to solve problems. This approach helps students develop their problem-solving, reasoning, reflecting, and communication processes. With this approach, students can work collaboratively to investigate a mathematical concept, work in centers, demonstrate skills or concepts, explain or justify their thinking, and provide peer feedback. During this process, educators can observe students, ask questions to help students understand concepts, help students justify answers or reflect on their solutions, address misconceptions, and encourage collaboration, discussion or alternative ways of thinking. Additionally, students need time to work in small groups or pairs because it enhances engagement, can encourage higher-order thinking, and can provide the

support students need to clarify a task and problem solve (Anthony & Walshaw, 2009). An example of this type of instruction is a math congress, where students work collaboratively to solve a problem and then participate in a gallery walk and group discussion to reflect on the different ways the problem was solved, the communication skills used, and the group's ability to represent and justify their answer (Small, 2012).

The second instructional approach in the *Guide to Effective Instruction in Mathematics, Kindergarten to Grade 6* by the Ontario Ministry of Education (2006) is guided mathematics. *Guided mathematics* is an instructional approach where the educator models and guides student through understanding a mathematical concept or skill. This allows the educator to model strategies, appropriate mathematical language, mathematical thinking, and problem-solving. During this process, students can observe and respond to demonstrated strategies, explain their own mathematical thinking, and participate in discussions. It also provides the opportunity for educators to connect concepts to students' prior knowledge, model problems and mathematical ideas and strategies, demonstrate the use of tools and manipulatives, refer to visual cues within the classroom, and pose meaningful questions. Additionally, educators can invite students to explain their thinking, listen to their peers, respect one another, and accept different ways of thinking (Anthony & Walshaw, 2009).

The final instructional strategy in the *Guide to Effective Instruction in Mathematics, Kindergarten to Grade 6* by the Ontario Ministry of Education (2006) is independent mathematics. *Independent mathematics* is an instructional strategy where students work independently to explore mathematical concepts, develop skills, communicate understanding, and solve problems. This does not mean that the student is isolated from all interactions, but rather that the student can function as an

autonomous learner who knows when and how to ask questions, develop strategies, and work through problems on their own using available tools and resources. During this process, students can communicate, develop, and demonstrate understanding, make personal decisions about appropriate strategies and tools, and problem solve. During this process, educators can interact with students, monitor student progress and activities, interview or conference with students, pose questions, and provide modifications or extensions to meet all students' individual needs. Students need time to work independently to give them time to grasp a new concept without the distraction of others' views or conflicting perspectives (Anthony & Walshaw, 2009). An example of this type of instruction is a bansho, where students work independently to solve a problem and then, through class discussion, the answers from the various students are combined to create an anchor chart for the classroom (Small, 2012).

In Paying Attention to Mathematics Education: Seven Foundational Principles for Improvement in Mathematics, K–12, the Ontario Ministry of Education (2011) explains that effective mathematics instruction is based on problem-solving and the exploration of mathematical concepts, builds on students' prior knowledge, is relevant to the students' lives, is differentiated to meet individual students' needs, is based on knowledge of students' mathematical development, and allows students to construct mathematical knowledge in an active, nurturing learning environment. In order to accomplish this, mathematics instruction must engage students in all the mathematical processes, allow flexible and varied ways of thinking, reasoning, meaning making, and concept development, include a variety of materials and tools, develop a mathematics learning community with student-student and student-teacher interactions, provide effective feedback and reflection, provide opportunities for cross-curricular connections, is authentic, and provide fair, equitable assessment and

evaluation. This means that educators must have opportunities for professional development that builds on teachers' pedagogical knowledge of mathematics teaching and learning, as well as opportunities to foster the integration of parents, school, and the community to work together to support student achievement (Anthony & Walshaw, 2009; Bruce, Esmonde, Ross, Dookie & Beatty, 2010; Jarvis, 2016; Ontario Ministry of Education, 2011).

All in all, it is important for educators to take a constructivist, investigative approach to mathematics education where students are actively involved in problem-based learning, giving them the opportunity to construct their own knowledge in an authentic, engaging environment in order to develop conceptual understanding of mathematical concepts (Anthony & Walshaw, 2009; Jarvis, 2016; Ontario Ministry of Education, 2005; Small, 2012). Activities that encourage students to analyse patterns and relationships while engaging in inquiry-based opportunities within a real world context allow students to see the key principles of mathematics, which will consequently encourage students to apply mathematical reasoning in other areas of their lives (Ontario Ministry of Education, 2005). Finally, effective instructional approaches activate students' prior knowledge, engage students in meaningful practice, incorporate a variety of tools and strategies, provide concrete representations through manipulatives, foster communication skills, and promote a positive attitude towards mathematics education (Anthony & Walshaw, 2009; Jarvis, 2016; Ontario Ministry of Education, 2005).

Technology-Enhanced Elementary Mathematics Education

The *Ontario Curriculum, Grades 1 – 8: Mathematics* by the Ontario Ministry of Education (2005) recognizes the benefits that technology can have on learning mathematics, and therefore encourages the integration of appropriate technology into

mathematics education. Technology can be used for whole-class instruction, as well as a tool to differentiate the learning to meet diverse student needs. It can be used to promote concept development through simulations, multimedia resources, and virtual manipulatives, as well as helping students develop communication skills. In addition, technology can help students become more globally aware through its ability to connect students to other schools in the surrounding area or abroad, bringing global cultures into the classroom. Technology can be used to help students extend their ability to investigate and analyse mathematical concepts, in addition to reducing the amount of time spent on computational activities. Technology can be used as problem-solving tools, exploration tools, and representation tools, while also building confidence and contributing to conceptual understanding. For example, technology can be used to decrease mathematics anxiety by making responses anonymous, such as through the use of clickers or by providing alternative ways to participate (Small, 2012). Interactive white boards also encourage participation and provide opportunities for lessons to be recorded for future reference.

One of the standards of the National Council of Teachers of Mathematics (NCTM) (2015) is the strategic use of technology in teaching and learning mathematics. This standard refers to the use of digital tools by students and teachers in a meaningful way and at thoughtfully determined times in order to enhance how students and teachers learn, experience, communicate, and understand mathematics. If used correctly, content specific mathematics technology can support students in investigating mathematical concepts and relationships, enhance student-teacher interactions, promote understanding of mathematical procedures, and develop students' ability to problem-solve, reason, and justify their answers. In order for this

to be done effectively, educators need to be knowledgeable in determining how and when digital tools are most beneficial to student learning (NCTM, 2015).

Jarvis (2016) found that some educators were not making the transition from traditional methods of teaching to reform-based mathematics education due to a perceived anxiety about managing their time, covering expectations, lack of confidence with the mathematics content, and managing student behaviors. Bennison and Goos (2010) state that educators need professional development opportunities in order to feel comfortable to try new teaching approaches such as the integration of technology. These workshops need to push beyond the *show-and-tell* type of activities that simply provide information on particular products that can assist in the teaching of mathematics. Instead, professional development opportunities need to show how specific mathematics topics can be taught using technology, with a focus on how to manage the technology in the classroom and how it can impact student learning. In other words, educators want practical ideas that relate to the daily routines and management of the classroom (Bennison & Goos, 2010).

As a result, it may be helpful to take routines or teaching strategies that educators are already using and demonstrate how they can be enhanced using technology. For instance, Small (2012) states that in order for students to develop conceptual understanding, it is essential for educators to provide concrete representations of mathematical ideas, such as manipulatives. For example, when exploring fractions, manipulatives can help students develop conceptual and procedural understanding using physical representations, which will assist them when moving onto more abstract ideas (Lee & Ferrucci, 2012; Small, 2012). This strategy has the potential to be enhanced using technology. In fact, Lee and Ferrucci (2012)

found that virtual manipulatives had a positive impact on students' understanding of fractions, while enhancing their thinking and creativity.

Therefore, the use of technology has the potential to enhance mathematics teaching and learning (NCTM, 2015; Ontario Ministry of Education, 2005; Small, 2012). However, in order to positively impact student learning, educators need to be knowledgeable in determining how and when digital tools are most beneficial (Jarvis, 2016; NCTM, 2015). These professional development opportunities need to focus on pedagogy such as daily routines and teaching strategies in order for educators to be willing to make changes in classroom practices (Bennison & Goos, 2010, Jarvis, 2016).

Student Engagement and Achievement

The concept of *student engagement* has been defined as the extent to which a student appears to be involved or interested in their learning, in addition to how connected they are to their class, school, and peers (Axelson & Flick, 2010).

Furthermore, *student engagement* can be defined as the relationship between the time, effort, and resources invested by all stakeholders to maximize student experience and optimise student development (Trowler, 2010). Harris (2008) argues that defining the concept of engagement is problematic due to the fact that there is a disagreement as to what counts as student engagement.

In this study, I have chosen to define student engagement using Fredricks, Blumenfeld, and Paris' (2004) definition, which describes engagement in three dimensions. *Behavioural engagement* includes the students' involvement in academic, social, and extracurricular activities. It is considered crucial for achieving a positive academic outcome. *Emotional engagement* is the positive and negative reaction to the learning environment including teachers, classmates, academics, and the school. It

creates ties to the institution and learning and can influence the students' willingness to learn and become involved. *Cognitive engagement* surrounds the idea of the thoughtfulness and willingness for students to produce the effort necessary to understand concepts and master skills (Fredricks et al., 2004). Furthermore, students can show positive engagement, non-engagement, and negative engagement in each dimension at different times (Trowler, 2010). Thus, the fusion of all three dimensions together creates the overall construct of student engagement.

Zepke and Leach (2010) performed a meta-analysis on articles pertaining to student engagement. Through a keyword search in several databases including the Web of Science, PsycINFO, ERIC, A+Education, Google Scholar, Academic Search Elite, General OneFile and Index New Zealand, the researchers found 283 items. These were then reduced to 93 relevant articles through inclusion and exclusion criteria. After synthesizing the remaining literature, the following proposals for increasing student engagement were developed. Enhancing students' self-belief that they are capable, while enabling them to work independently, will increase students' intrinsic motivation to complete tasks. Additionally, teachers' relationships with the students must be positive, caring, and encouraging to create an environment that fosters collaborative learning and enriches educational experiences. Institutions must also encourage engagement through welcoming diverse backgrounds and investing in support services in order to change student expectations and develop a positive, inclusive school environment. Finally, enabling students to develop their social and cultural awareness challenges social beliefs and practices, thereby increasing student engagement in active citizenship.

Many researchers have examined how the use of technology in the classroom affects student engagement and motivation. In this study, the terms *digital tool* and

technology refer to any device that uses hardware, such as computers, tablets, and mobile phones, or software, such as operating systems and application programs (JMC, 2011). Cicconi (2014) explains that technology allows students to take on the role of the expert, redefining the types of learning experiences accessible to students. Additionally, using technology can engage students in collaborative exercises that deepen their understanding of math concepts through relevant and authentic learning experiences (Cicconi, 2014). Moreover, Eyyam and Yaratani (2014) surmised that both students and teachers benefit from the use of technology within learning environments, including seeing an increase in learning capabilities, motivation, and engagement. Furthermore, Bray and Tangney (2016) found that digital tools can make mathematics more meaningful, practical, and engaging by allowing students to solve problems in contexts which help develop a sense of ownership over their learning, thus resulting in improved attitudes, behavior, and confidence.

Carini, Kuh, and Klein (2006) state that student engagement is considered to be one of the best predictors of learning among post-secondary students. Marks (2000) made this same connection when examining patterns among elementary, middle, and high school students, stating that pupils who are engaged in school are more likely to learn, graduate, and continue onto higher education. In other words, the more positive engagement exhibited by the student while exploring a concept, the more likely they are to learn and understand it. Additionally, research has shown that positive behavioral engagement is correlated with higher achievement scores, while negative behavioral engagement has been shown to be a precursor to students dropping out of school (Fredricks et al., 2004). *Student achievement* has been defined as the extent of conceptual growth as determined by measures of student performance

(Hegedus, Tapper & Dalton, 2016). Therefore, student engagement has been shown to be a good predictor of student achievement (Carini et al., 2006; Marks, 2000).

The use of technology within the learning environment has been shown to increase student engagement (Bray & Tangney, 2016; Cicconi, 2014; Eyyam & Yaratan, 2014; Schibeci, Lake, Phillips, Lowe, Cummings & Miller, 2008). In addition, student engagement is a good predictor of student achievement (Carini et al., 2006; Marks, 2000). Coincidentally, it can be hypothesized that the use of technology within the learning environment may have the ability to increase student achievement. However, some studies examining the impact of using technology in the classroom have found a negative or null effect on some aspect of student achievement.

Carrasco and Torrecilla (2012) completed a study on the effect of computer access on the student achievement of Latin-American Grade 6 students. They found that students who used a computer at home to do homework achieved lower marks in math and reading than children who did not. Likewise, Carr (2012) completed a quantitative, quasi-experimental study to examine the effects of 1:1 iPad use on 104 fifth grade students' mathematics achievement. The study found that iPad use had no significant effect on student achievement. Therefore, while the use of technology in the classroom has a positive effect on student engagement, which is a strong predictor of student achievement, technology is not always found to have a positive effect on student learning.

Evaluating Technology

Blake, Davies, Jones, Morris and Scanlon (2003) argue that through the evaluation of educational technology, educators can determine whether the digital tool will impact teaching and learning. In fact, Blake et al. (2003) suggest three areas for evaluating digital tools. First, educators must examine the context of using the digital

tool. This includes the wider context, such as teaching strategies and classroom activities, all the way to the smaller context, such as the digital tool used within the unit. Questions that need to be asked are will the work be collaborative or independent? What is the rationale for using the digital tool? The second stage is to collect information about the process in order to record success, but to also find areas for improvement, as well as examining student interactions. Finally, educators must analyze the attitudes and outcomes of using the digital tool (Blake et al., 2003).

Squires and Preece (1999) offer a model of evaluation that precedes using the digital tool to predictively evaluate educational technology. Digital tools should keep users informed about what is going on, connect to the real world by using phrases and concepts familiar to the user, allow the user control and freedom, be consistent in words, situations, and actions, have error prevention, make actions and objects available in order to focus on recognition instead of recall, information and instructions should be visible or easily retrievable, flexible and easy to use for inexperienced and experienced users, simple design, and provide help to users when required (Squires & Preece, 1999). In other words, educators should be using predictability evaluation techniques as well as data collection during and after the process in order to effectively evaluate the impact of a digital tool. This information will help educators gain personal experience to make valuable judgements on further educational tools and their potential impact on student achievement (Blake et al., 2003; Squires & Preece, 1999).

Lee and Cherner (2015) explain that not all educational technology is equally beneficial. They report that there are over 20, 000 iOS education apps available in the App Store, resulting in the fact that teachers need support to filter out the inferior apps in order to identify the quality apps they should use in the classroom. In other words,

educators need to be examining the functionality of digital tools in order to determine if the digital tool or educational technology has the potential to impact student achievement. *Functionality* can be defined as the functions that allow the user to interact with the tool (Lee & Cherner, 2015). In this study, I have decided that the term *functionality* will refer to the operations, features, or capabilities that can be performed using the digital tool that usually contributes to the interaction between the tool and the user. Therefore, through the evaluation of the functions used to interact with the users, educators can predict the potential impact the tool may have in the classroom. In order to support teachers through this evaluation, several researchers have attempted to create rubrics.

For instance, Lee and Cherner (2015) developed a rubric for evaluating educational apps based on previously conducted research on the methods used to evaluate technology for educational purposes. Through this research, they developed a rubric with 24 evaluative dimensions aligned to a 5-point Likert scale. The rubric was then examined by two groups of experts, who then critiqued the rubric, resulting in some modifications and revisions. After a final presentation to the experts, the final rubric was published. The rubric was divided into three domains. The first domain was used to determine the instructional worth of the app through evaluation of the level of higher- order thinking required of the user, the development of 21st century skills, connections to curriculum standards, the ability to let users learn from mistakes, the ability for the teachers to monitor users' progress, the challenge level in relation to the audience, ability for users to collaborate, and ability to accommodate individual differences (Lee & Cherner, 2015).

The second domain in Lee and Cherner's (2015) rubric is to examine the user's interaction with the app in order to determine the efficiency and ease of use.

Specifically, educators examine the app's ability to save users' progress, the app's ability to interact with other platforms, the screen design and organization, the ease of use or its ability to be user-friendly, users' navigation through the app, whether each component of the app contributes to the learning goals, how the app presents information, how the app integrates different forms of media such as visuals, graphics, and videos, and the app's ability to accommodate different cultures or backgrounds (Lee & Cherner, 2015).

Finally, the third domain in Lee and Cherner's (2015) rubric examines the app's ability to engage and motivate the users. Specifically, educators examine whether the app allows users to choose the level of difficulty, has an engaging instructional experience, allows users to control the speed at which they move through the content, allows the users to personalize settings, whether the app will appeal to the audience, whether the app is visually appealing, and whether the users will find the app beneficial to their academic, professional, or personal lives (Lee & Cherner, 2015).

Schibeci et al. (2008) did not create a rubric; rather, the researchers examined over 40 learning objects in order to determine the characteristics or functions of successful tools. *Learning objects* were defined as any file or chunk of material designed to be used as a learning experience that works alongside other digital and non-digital resources, is accessible through the internet, and can be tracked using a learning management system. These learning objects included talking books, digital or virtual drills to practice and assess skills, tools used to perform tasks more efficiently, activities where students investigate concepts or produce a product, simulations, and interpretative activities that allow the user to select the content and product. They determined that the learning object was more successful if it

encouraged exploration of concepts, motivated users, used gaming characteristics such as rewards or a point system, was relevant to learning purposes, the difficulty level was suitable to the user, instructions were provided only when needed, the learning purpose was shared, the object was user-friendly, the learning object provided feedback, content was differentiated, and the learning object had the ability to interact with other programs such as a word processing software. Additionally, successful learning objects avoided text-intensive instructions or text-intensive inputs from users, sound was available when needed, video clips were easily interpreted by users, and animations were used to highlight important ideas (Schibeci et al., 2008).

Thus, not all digital tools are equally beneficial to student learning, which could contribute to the fact that some studies are finding digital tools to have a negative or null impact on student achievement. This means that educators need to be supported to evaluate the functionality of digital tools in order to predict their potential impact on student achievement.

Integrating Technology

Several researchers have explained the disconnect between technology and student achievement in a different way. Kinchin (2012) refers to this disconnect as *technology-enhanced non-learning*. He argues that *technology-enhanced non-learning* is the product of the ineffective integration of educational technology due to the pressure on educators to incorporate digital tools in the classroom. This leads to educators forcing technology into traditional teacher-focused teaching methods. The National Forum for Education Statistics (2002) defined *technology integration* as the use of technology resources and technology-based practices in daily routines, school work, and the management of schools to support school goals and purposes. In this study, I have defined the *integration of technology* as the instructional methods,

pedagogy, or teaching strategies used to incorporate the use of technology or digital tools into curriculum, routines, or day-to-day practices.

Thomas and Hong (2013) explain that a teachers' pedagogical technology knowledge is the bank of teaching strategies required to teach mathematics through the use of educational technology. In other words, teachers need to use technology to scaffold mathematics learning while understanding that digital tools can be used in a variety of ways and students may benefit more from one way than another. Many researchers have examined this idea, adapting the TPACK Framework as a model for the knowledge needed to effectively integrate technology into the classroom. Developed by Dr. Punya Mishra and Dr. Matthew Koehler, the TPACK Framework outlines three primary forms of knowledge: *content knowledge*, *pedagogical knowledge*, and *technological knowledge*, along with how the three types of knowledge intersect in order to construct the technological pedagogical content knowledge an educator needs to effectively teach with technology (Koehler & Mishra, 2008; Koehler, 2011).

However, the purpose of the TPACK Framework is to identify the knowledge needed to teach with technology effectively – not to be used as a model of integration to help select, evaluate, or instruct on the use of technology within the classroom (Green, 2014; Koehler & Mishra, 2008; Koehler, 2011). Additionally, Green (2014) argues that the SAMR Model used by many may not be valid due to the limited published research documenting the development and validation of the model. Developed by Dr. Ruben Puentedura, the SAMR Model defined the different levels of technology tools and their use within the classroom. However, by using the SAMR and TPACK models to organize digital tools and formulate strategies for integration, the functionality of the tools becomes the focus of the integration, rather than the

pedagogy and teaching strategies that are already proven in research to have a benefit to student achievement.

Campe (2011) would agree with Green (2014), arguing that simply using technology within the classroom is not enough. In other words, the functionality of the digital tool needs to be aligned with effective pedagogy in order for educators to use the technology to its full potential. Campe (2011) states that before the lesson, the educator must educate themselves on the functionality of the tool, decide whether the tool will work better with students working collaboratively or independently, examine ready-made materials, prepare directions and demonstrations of the digital tool, consider pre-requisite skills, design the lesson to build understanding, be willing to allow exploration, and scaffold student learning. During the lesson, educators should let the students play with the tool without interference, change group roles, clarify expectations, use questioning to give help, use checkpoints, use all of the technology's available functions, and be prepared for technology failure. After the lesson, educators should debrief with the students, assess student understanding, and reflect on the lesson.

This process is similar to the general expectations of teachers when planning a lesson. Wiggins and McTighe (2006) describe the *learning plan* as the time when educators think about the learning experiences and activities that will help students achieve the desired results. In this model, educators should know where the unit is going, what is expected and what the students' prior knowledge is. They should then hook the students, allow them to explore and experience the learning objectives, and allow them to rethink, revise, and evaluate their work. Educators should differentiate the learning experience, make sure it is engaging, and be reflective after the lesson.

In other words, the process of creating a lesson with technology is similar to creating a lesson without technology (Wiggins & McTighe, 2006; Campe, 2011). However, if teachers have a low level of confidence in using technology, a limited number of opportunities to develop strategies for teaching with technology, a resistance to change or negative attitude towards using technology, a limited amount of time, a limited number of resources, or a lack of technical support, teachers are unable to apply their pedagogical knowledge to integrating technology (Bingimlas, 2009; Thomas & Hong, 2013). Without this knowledge, the students end up with technology-enhanced non-learning (Kinchin, 2012).

According to Delgado, Wardlow, O'Malley and McKnight (2015), the most common strategies of technology integration include bring your own device (BYOD), blended learning or hybrid courses, flipped learning, and online learning or distance education. In BYOD environments, every student brings their own personal digital device to school to be used within the learning environment. Blended learning, hybrid, courses, and flipped learning refers to an environment where instruction is given both virtually and face-to-face. In an online learning environment, most of the instruction is given virtually, with limited face-to-face interaction (Delgado et al., 2015). However, most research examines these strategies in terms of the proportion of time spent learning online or the digital tools that have the functionality needed to facilitate them, not the pedagogical strategies or teaching decisions that best align to each type of integration.

The research presented in this chapter examined the literature surrounding student engagement, student achievement, the evaluation of technology, and the integration of technology. Student engagement is a good predictor of student achievement (Carini et al., 2006; Marks, 2000). Using technology in the classroom

has been shown to increase student engagement, but it does not always positively impact student achievement (Bray & Tangney, 2016; Carr, 2012; Carrasco & Torrecilla, 2012; Cicconi, 2014; Eyyam & Yaratana, 2014; Schibeci et al., 2008). By correctly evaluating digital tools for their potential impact on student learning, and then aligning these tools to the correct pedagogical strategies, educators can ensure that digital tools will have an impact on student engagement and achievement (Blake et al., 2003; Lee & Cherner, 2015; Schibeci et al., 2008; Squires & Preece, 1999). However, models of technology integration and strategies for the integration of technology focus on functionality and time online rather than the pedagogical strategies that benefit student learning (Green, 2014).

The next chapter outlines the methodology used in this study to examine the functionality of digital tools and the qualities of technology integration that most impact student learning in order to develop strategies for evaluation and integration that focus on pedagogy and functionality.

CHAPTER THREE: METHODOLOGY AND RESEARCH DESIGN

This chapter discusses the methodology used in this study. The first section describes the research methodology and design of the study, followed by how the data was collected and analysed. The fourth and fifth sections outline the methodological assumptions and limitations of the study. Finally, the chapter will end by discussing the credibility of the study, followed by a restatement of the area of study.

Research Methodology and Design

This systematic review integrated the findings from existing research on the impact of technology in elementary mathematics classrooms using a meta-analytic approach. Card and Little (2012) argue that due to studies being conducted at an increasing rate, it is difficult for scholars to stay informed of research outside their area of specialization, which can minimize the connections between areas of study. *Meta-analysis* is the process of summarizing and comparing results from existing literature, making it possible to gain new insights and conclusions based upon a high number of existing, credible studies (Card & Little, 2012). In this study, meta-analysis allows for a systematic review of recent research examining the impact of technology in elementary mathematics classrooms. Once collected, these studies can be analysed and compared to examine the commonalities between the functionality of the technology used, how the technology was integrated into the classroom, and whether or not the study found a positive effect on student achievement and student engagement.

Data Collection

Meta-analysis differs from other types of reviews by devoting attention to the systematic approach taken to locate and retrieve relevant literature (Card & Little,

2012). In this study a three-part system was used to collect the articles to be used in the analysis.

Selection of Keywords

To decide on the keywords that would bring about the most relevant articles, four keyword categories were selected (see Figure 3.1). The mathematics category included the keywords *math*, *mathematics*, and *mathematical*. The effects category included the keywords *impact*, *affect*, *effect*, *influence*, *implication*, and *outcome*. The student success category included the keywords *learning*, *achievement*, and *performance*. The technology category included the keywords *technology*, *technologies*, *computer*, and *digital*.

Selection of the Database and Limitations

A keyword search using the above terms was completed using a single database. The search was limited to peer-reviewed articles in order to increase credibility. In addition, the articles were limited to those published since 2010 to account for recent technological and educational advances.

The Education Resources Information Center (ERIC) is an online database of indexed and full-text educational literature featuring resources from journals included in the *Current Index of Journals in Education* and *Resources in Education Index* (EBSCO Industries, 2016b). After trying 72 searches in ERIC using variations of the keywords above, it was decided to switch to a different database that may supply a higher number of relevant articles.

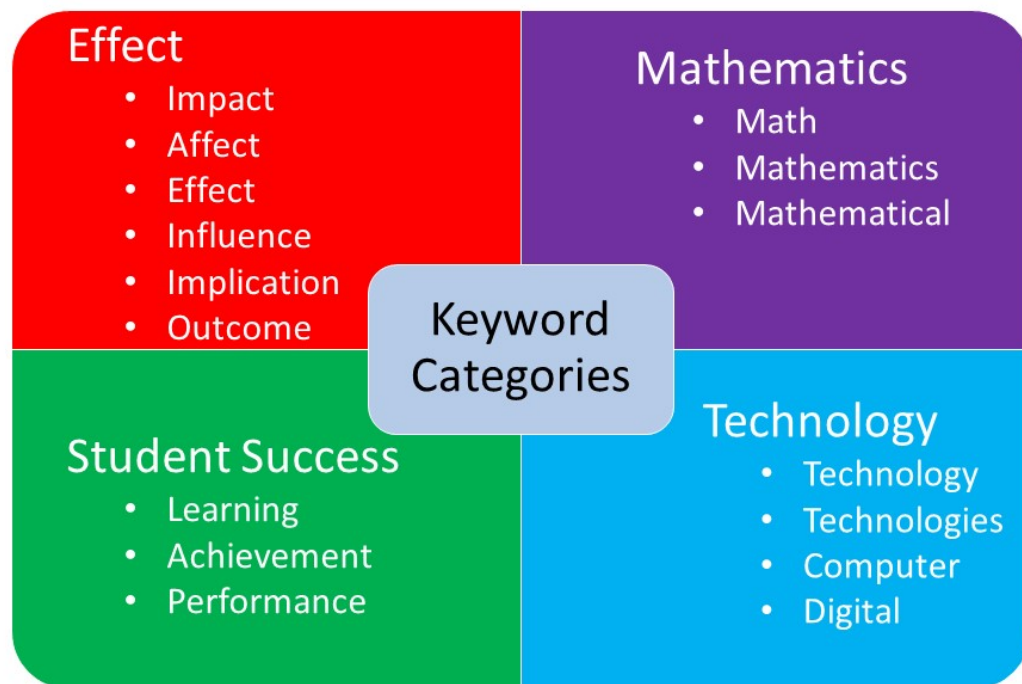


Figure 3.1. Keyword Categories. This is an illustration of the keywords included in each category.

Academic Search Complete is designed for academic institutions as a database of leading resources for scholarly research. Since it has access to over 7,700 full text, peer-reviewed journals supporting several key areas of academic study including education, technology, and mathematics, it was decided to do two different searches, both in Academic Search Complete (EBSCO Industries, 2016a).

The initial search involved the keyword search *technology AND math AND elementary*, resulting in 298 articles. The second search involved the keyword search *(technology OR computer OR digital) AND math* AND (impact OR affect OR influence OR effect OR implication OR outcome) AND elementary AND (achievement OR learning OR performance)*, resulting in 236 articles. 67 of these articles were duplicates, resulting in 467 unique articles in total. The citations and abstracts of all 467 articles were then copied into Excel 2016 for further analysis.

Inclusion and Exclusion Criteria

A series of inclusion and exclusion criteria was created in order to narrow the results down to the most relevant articles to include in the data analysis (see Figure 3.2). First, the articles were excluded if they were not available in English. Although this is a limitation to the study, the researcher is only fluent in English. Second, because this research study focuses on elementary mathematics, only abstracts with a connection to elementary students or teachers were included. In this study, elementary refers to students aged 10 to 14, which correlates to Grades 4 – 8 in Ontario, Canada.

One by one, each abstract was copied into Word 2016. Using the ‘replace’ function, all of the keywords in the mathematics and technology category were replaced with a text- coloured version of themselves, and then the whole abstract was copied back into Excel 2016. Excel 2016 was then used to examine the abstracts and record results. Articles were excluded if they did not have at least one keyword from

both categories. If no keyword was found, the abstract was searched for other words related to the mathematics category such as subject specific terms like *algebra*, or the technology category such as *mobile*, *software*, or *online*. Furthermore, articles were excluded if they had keywords from both categories, but they were not the focus of the study. For example, Voogt (2010) had the keywords *technology* and *math* in the abstract. However, this article was examining the differences in teachers' curriculum goals and pedagogical practices between science teachers that use technology and those that do not. Therefore, even though this article had at least one keyword from both categories, it was focusing on science and not mathematics, so it was excluded.

Fourth, the remaining abstracts were again copied into Word 2016 and the 'replace' function was used to replace all of the keywords in the effect category with a text-coloured version of itself, and then the whole abstract was copied back into Excel 2016. Excel 2016 was then used to examine the abstracts and record results. Articles were excluded if they did not have at least one keyword from this category. If no keyword was found, the abstract was searched for other words related to the effect category such as *improve*, *benefits*, or *relationship*. Additionally, articles were excluded if the effect keyword was not used in reference to technology. For example, Cotabish, Dailey, Robinson and Hughes (2013) had the keyword *effect* in their abstract. However, this study was examining the effect of an elementary Science, Technology, Engineering, and Mathematics (STEM) program – not the effect of a digital tool.

Therefore, if the article was in English, was connected to elementary students or teachers, was focused on mathematics and technology, and examined the effect of technology, the article was included. This process resulted in 47 articles being

included in the data analysis. Results of the inclusion and exclusion decisions were recorded using Excel 2016 (see Appendix A).

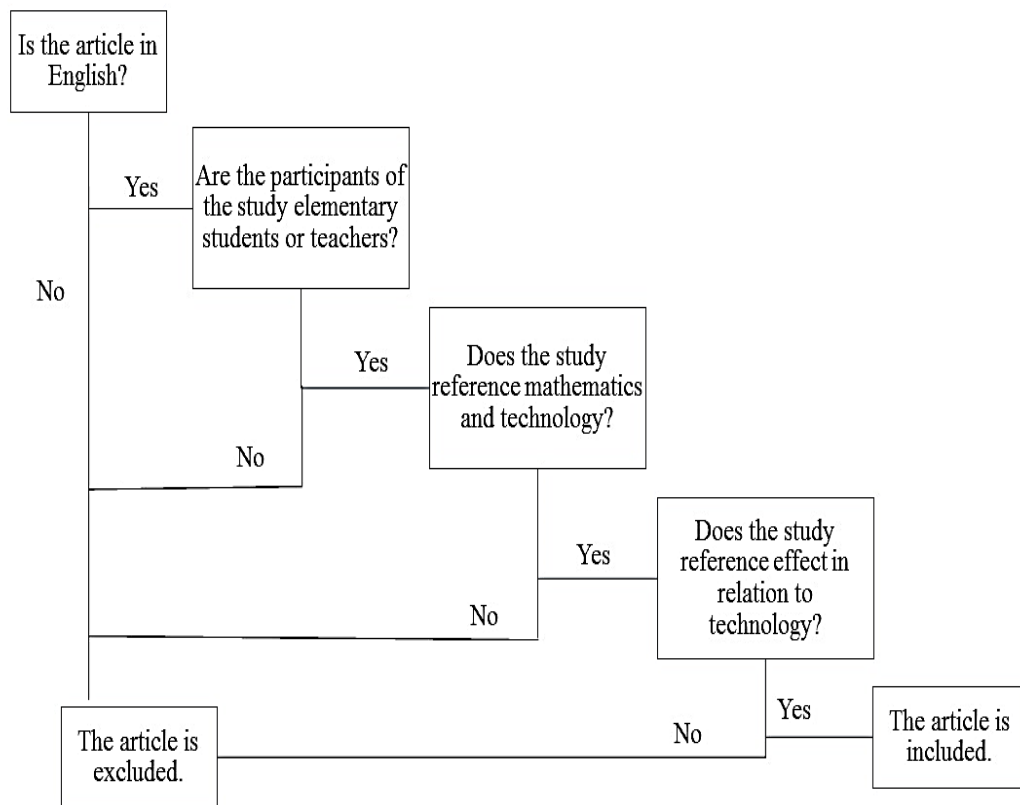


Figure 3.2. Inclusion and Exclusion Criteria Flow Chart. This figure illustrates the process of including and excluding articles in the meta-analysis.

Data Analysis

After systematically retrieving 47 relevant articles, the next step in performing the meta-analysis was to code the studies (Card & Little, 2012). All 47 included articles were obtained in full-text and uploaded to QDA Miner 4 Lite. QDA Miner 4 Lite is a qualitative analysis software that allows the user to analyse textual data through coding, commenting, text retrieval, and text analysis functions. This software is free, easy to use, and provides the coding and text-retrieval features needed for the meta-analysis.

In order to identify the methodological characteristics that might contribute to answering the research questions, a two-tier coding system was used. First, all articles were coded using macro-codes aligned to the research questions, findings, and age of the participants. The macro-coding scheme included selecting sections of text that described the integration of the digital tool, the functionality of the digital, findings, and age of participants (see Table 3.1).

Table 3.1

Description of Macro-Codes

| Term | Description |
|---------------|--|
| Integration | The instructional methods, pedagogy, or teaching strategies used to incorporate the use of technology or digital tools into curriculum, routines, or day-to-day practices. In other words, how is the digital tool used? |
| Functionality | The operations, features, or capabilities that can be performed using the digital tool, usually contributes to the interaction between the tool and the user. In other words, what can the digital tool do? |
| Findings | The positive, negative, or null outcomes of the study. |
| Age | The age or grade of the participants in the study. |

The first set of codes were pre-selected so that they aligned to the research questions. However, the second tier of coding terms could not be pre-selected, or the findings would be at risk of researcher bias. Therefore, the ‘text retrieval’ tool in QDA Miner 4 Lite was used to copy the text selected for each of the macro-codes into Excel 2016. Excel 2016 was then used to record and sort information from the sections into micro-codes created from information provided within the selected text.

Text selected under the ‘age’ macro-code was used to examine the number of each age group represented in the studies. Each article’s citation was used as a row heading. Ages found within the text sections became the micro-codes, and were placed as the column headings (see Figure 3.3). The selected text for each article was then scanned for the age of the participants, which was then used to put a one in the matching cell. Totals for each column were then calculated using the ‘sum formula.’

The ‘findings’ macro-code was used to record whether or not the study resulted in positive, negative, or null findings on student achievement, student engagement, or some other factor of learning. Each article’s citation was used as a row heading. The terms *positive impact*, *negative impact*, and *null impact* became micro-codes and were placed as column headings. The terms *student achievement*, *student engagement*, and *other* also became a second set of micro-codes, and were placed as subheadings under each of the terms in the first set of micro-codes (see Figure 3.4). The selected text under the findings macro-code for each article was then scanned for the positive, negative or null outcomes on student achievement, student engagement, or other factors of learning. The number ‘one’ was then put in the matching cell. Totals for each column were calculated using the ‘sum formula.’

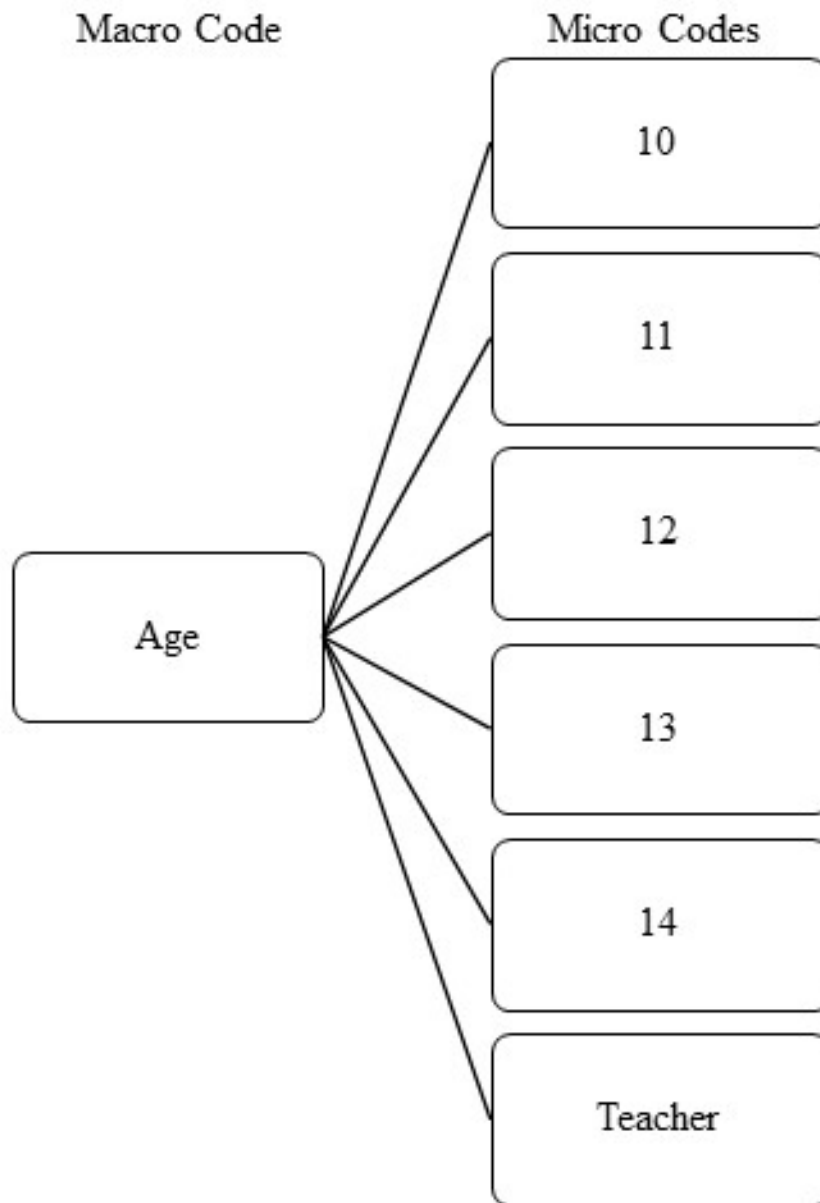


Figure 3.3. Age Macro-Code. This figure illustrates the relationship between the age macro-code and its micro-codes.

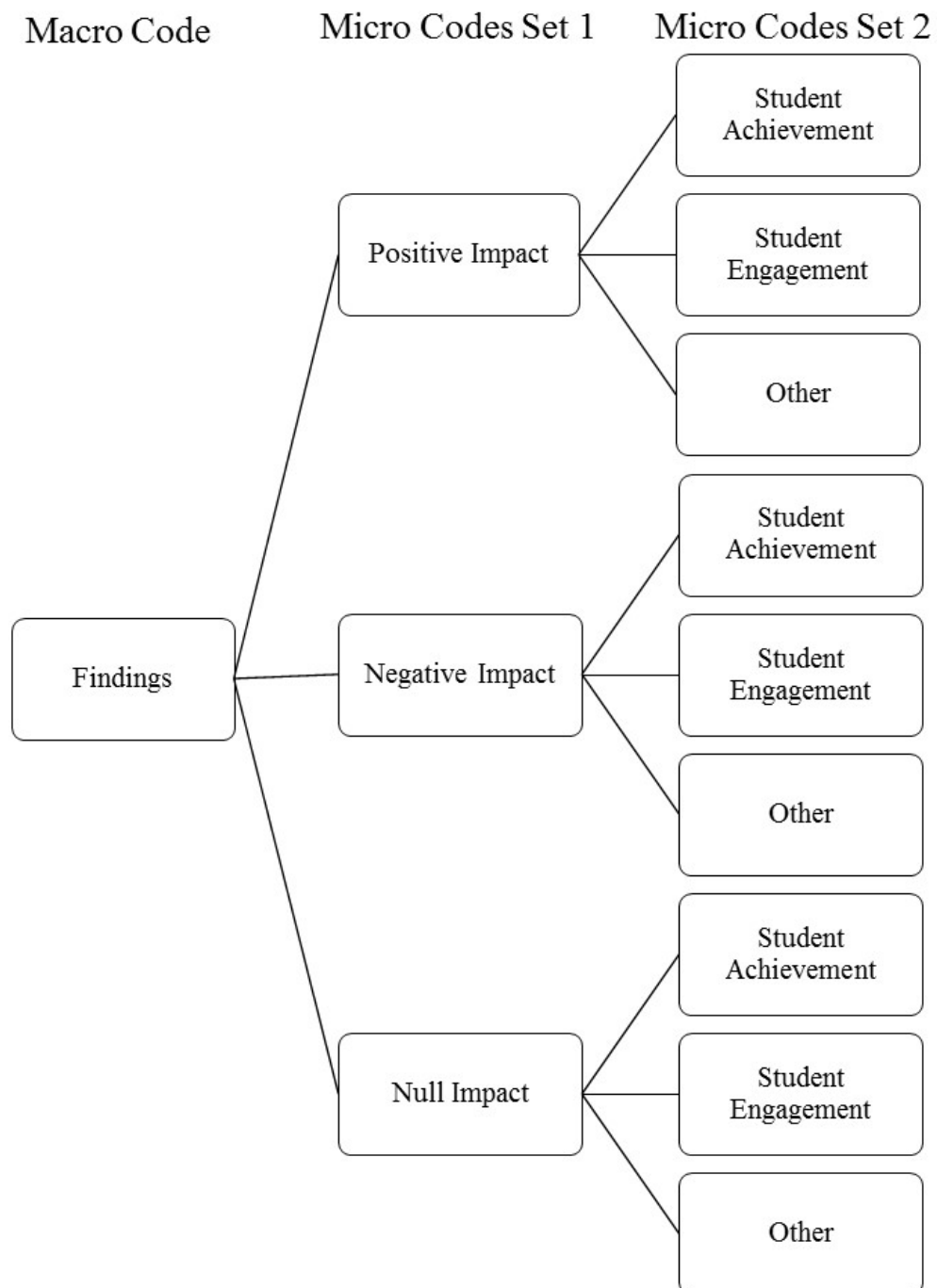


Figure 3.4. Findings Macro-Code. This figure illustrates the relationship between the findings macro-code and its micro-codes.

A similar process was used separately for both the ‘integration’ and ‘functionality’ macro-codes, which each examined the qualities of technology integration and the functions of the digital tools, respectively. Each article’s citation was used as a row heading. The text from the ‘integration’ macro-code was analysed for qualities of integration, while the text from the ‘functionality’ macro-code was analysed for reported functions. As a new quality or function was presented, it became a new micro-code (see Table 3.2 and Table 3.3) and was placed as a column heading. The text selected for each article was then scanned for a connection to each micro-code, and the number ‘one’ was put in the columns of each micro-code it reported. If a study did not directly report a quality or a function, it was not recorded, even if there was reason to believe the quality or function would be present. Totals for each column were then calculated using the ‘sum formula.’

These spreadsheets were analysed and compared to the findings spreadsheet. During this second tier, an article could be excluded from the integration or functionality analysis if a sufficient description of the qualities of functionality and integration was not provided (see Appendix B and C).

Table 3.2

Description of Integration Micro-Codes

| Term | Description |
|---|--|
| Concepts Taught Before and/or After | The mathematical concepts or learning goals were taught before or after using the digital tool. |
| Connected to Concepts Being Studied | The use of the digital tool is connected to the current mathematical concepts being studied by the students. |
| Feedback Provided from the Teacher | Feedback on student progress or understanding of the mathematical concepts is provided by teacher. |
| Had Time to Interact with the Technology Before Study | The students had time to interact and become familiar with the digital tool before the study took place. |
| Help with Concepts Provided | The teacher or researcher provided help with the mathematical concept during technology use. |
| Help with Software/Hardware | The teacher or researcher provided help with the software or hardware during technology use. |
| No Teacher Participation/Intervention | The teacher did not provide help or intervene with technology use in any way. |
| Parent Participation | Parents of the students participated in the use of technology. |
| Professional Development | Professional development on technology use or technology integration was provided to the teachers. |
| Student - Teacher Conference | A student-teacher conference on the use of technology or mathematical concepts was completed. |
| Students Learn at their Own Pace | Students were able to use the technology or learn the mathematical concepts at their own pace. |
| Students Working Collaboratively | Students had the opportunity to work collaboratively in groups of two or more. |
| Students Working Independently | Students had the opportunity to work independently. |
| Support for Teachers During Integration | Teachers were provided continuous support during the study on technology use or technology integration. |
| Teacher Facilitating the Learning | Teachers facilitated the learning of mathematical concepts. |

Table 3.3

Description of Functionality Micro-Codes

| Term | Description |
|--------------------------|---|
| Adaptive | The digital tool adapts to the ability level of the user. For example, questions will become more challenging as the user improves and easier if the user is struggling so that challenge level suits the user. |
| Animation | The tool uses moving images. |
| Avatar | The users have an icon or figure that represents them within the tool. |
| Blogging | The user can post to a blog. |
| Collaboration | Users are able to collaborate with one or more other users within the digital tool. |
| Draw/Write/Highlight | The user can draw, write, or highlight text within the tool. |
| Game-Based Environment | The tool uses games or game features within the environment. |
| Graphics/Visuals | The tool has graphics or visuals. |
| Hints/Help | The tool provides hints or help to the users. |
| Learning Outcomes Shared | The learning outcomes or learning goals are shared explicitly with the user. |
| Manipulative | The tool has the ability for users to manipulate objects. |
| Messaging | The tool has the ability for users to message other users through instant messaging, emails, chat rooms, or video conferencing. |
| Presentation Software | The tool provides access to presentation software such as PowerPoint. |
| Provides Feedback | The tool provides feedback to the user on technology use or the understanding of concepts. |
| Rewards/incentives | The tool provides rewards and incentives to users. |
| Robotics | The tool is connected to the use of robotics. |
| Role Playing Game | The tool provides a game where the user takes on a role within the game. |
| Shows Correct Answer | The tool shows the user the correct answer. |
| Spreadsheet | The tool provides access to spreadsheets such as Excel. |
| Students Create Content | The tool allows users to create content. |

| | |
|------------------------------|--|
| Teacher Dashboard | The tool provides teachers with a location to access records, feedback, and information on student users |
| Tied to Curriculum | The concepts or goals within the tool are directly connected to curriculum standards. |
| Time Limit | The tool provides a time limit to users. |
| Tool is for Assessing Skills | The tool is mainly used to assess the skill of users through question/answer activities. |
| Tutorial on Concept | The tool provides a tutorial on mathematical concepts. |
| User-Friendly | The tool is easy for users to use. |
| Virtual Guide | The tool provides instructions for using the tool or understanding concepts through a virtual guide. |
| Virtual World/Classroom | The tool provides access to a virtual world or area similar to a classroom. |
| Word Processing Software | The tool provides access to word processing software such as Word. |

Methodological Assumptions of this Study

The methodological assumption of this study is that meta-analysis is an appropriate and valid means to answer the research questions. In order to analyse qualities of technology integration and functionality of digital tools compared to the findings, it was assumed that findings presented within the selected articles were the result of the integration and functionality of the technology or digital tool, and not influenced by the methodology or limitations of the study itself.

Limiting the articles to those that were peer-reviewed should increase the probability that the data collection and data analysis of those articles produced reliable results and that the researcher drew valid conclusions and implications from their findings. This would result in a higher probability that the articles were trustworthy. In addition, the number of articles that reported each micro-code was recorded and taken into consideration during the interpretation of the findings in order to minimize the effect that each study's methodology had on the meta-analysis findings.

Limitations of this Study

Analysis of the integration and functionality of the technology is limited to the descriptions given within the study. Although studies with insufficient information are filtered out due to the exclusion criteria in the second tier of coding, this limits the number of valuable articles included in the study.

According to Card and Little (2012), studies that result in null or insignificant findings tend to not be published. In addition, articles are limited to those published in English. Both attributes will result in a publication bias.

Validity and Reliability of this Study

In order to ensure this study was reliable, the collection of relevant articles and the decisions to include or exclude articles was based upon a systematic set of replicable steps instead of a decision based on researcher opinion.

In order to ensure the study was trustworthy and valid, the database used was selected due to its credibility in the research community. All included articles were peer-reviewed and all decisions for excluding articles were recorded and included in the appendix (see Appendix A, B, and C). In addition, all articles were published from 2010 onwards in order to obtain the most recent, relevant studies.

Restatement of the Area of Study

A meta-analysis of recent research on the impact of technology was conducted in order to examine the functionality of digital tools and the integration of those digital tools that most impact student achievement and student engagement. Through a keyword search and exclusion criteria, a systematic collection of relevant articles was completed, followed by a two-tier coding scheme to analyse the findings, which can be found in the next chapter.

CHAPTER FOUR: PRESENTATION OF RESULTS

This chapter discusses the findings of a meta-analysis completed to examine the functionality of digital tools and the qualities of technology integration that most impact student achievement and engagement. Two keyword searches were completed in Academic Search Complete, resulting in 467 different articles. In order to narrow the list down to the most relevant articles to be used in the analysis, abstracts from all 467 articles were copied into Excel 2016. Through the use of exclusion and inclusion criteria, these articles were narrowed down to 47 relevant articles to be used in the data analysis. After implementing a two-tier coding scheme using QDA Miner 4 Lite, Excel 2016, and Word 2016, spreadsheets on the age of the participants, the findings, and the functionality and integration of technology were created, analysed, and compared (see Appendix D). This chapter will begin by discussing the findings of the included studies in terms of student achievement, student engagement, and other factors of learning. It will then discuss the findings related to the qualities of functionality and the qualities of integration found to have the most impact on student achievement, student engagement, and other factors of learning. Lastly, this chapter will report the ages of the participants within the included articles.

Findings of the Included Studies

The text selected under the ‘findings’ macro-code was further categorized by positive, negative, or null findings on student achievement, student engagement, or other factors of learning. If a study reported more than one finding, both or all the findings were coded separately.

Student Achievement

In this study, student achievement was defined using Hegedus, Tapper, and Daltons’ (2016) definition which describes *achievement* as the extent of conceptual

growth determined by measures of student performance. Of the 47 articles included in the data analysis, 41 (87.23%) reported on student achievement. Out of the 41 articles that reported on student achievement, 36 (87.80%) of the articles found a positive effect on some aspect of student achievement, 7 (17.07%) of the articles found a negative effect on some aspect of student achievement, and 11 (26.83%) of the articles found a null effect on some aspect of student achievement (see Figure 4.1).

Student Engagement

In this study, student engagement was defined using Fredricks, Blumenfeld, and Paris' (2004) definition which describes engagement as the fusion of behavioural, emotional, and cognitive engagement. Of the 47 articles included in the data analysis, 12 (25.53%) reported on student engagement or motivation. Out of the 12 articles that reported on student engagement or motivation, all 12 (100%) of the articles found a positive effect on some aspect of student engagement or motivation, 1 (8.33%) of the articles found a negative effect on some aspect of student engagement or motivation, and 2 (16.67%) of the articles found a null effect on some aspect of student engagement or motivation (see Figure 4.2). Since, 100% of articles that reported on student engagement and motivation found a positive effect, further analysis will focus on student achievement and other factors of learning.

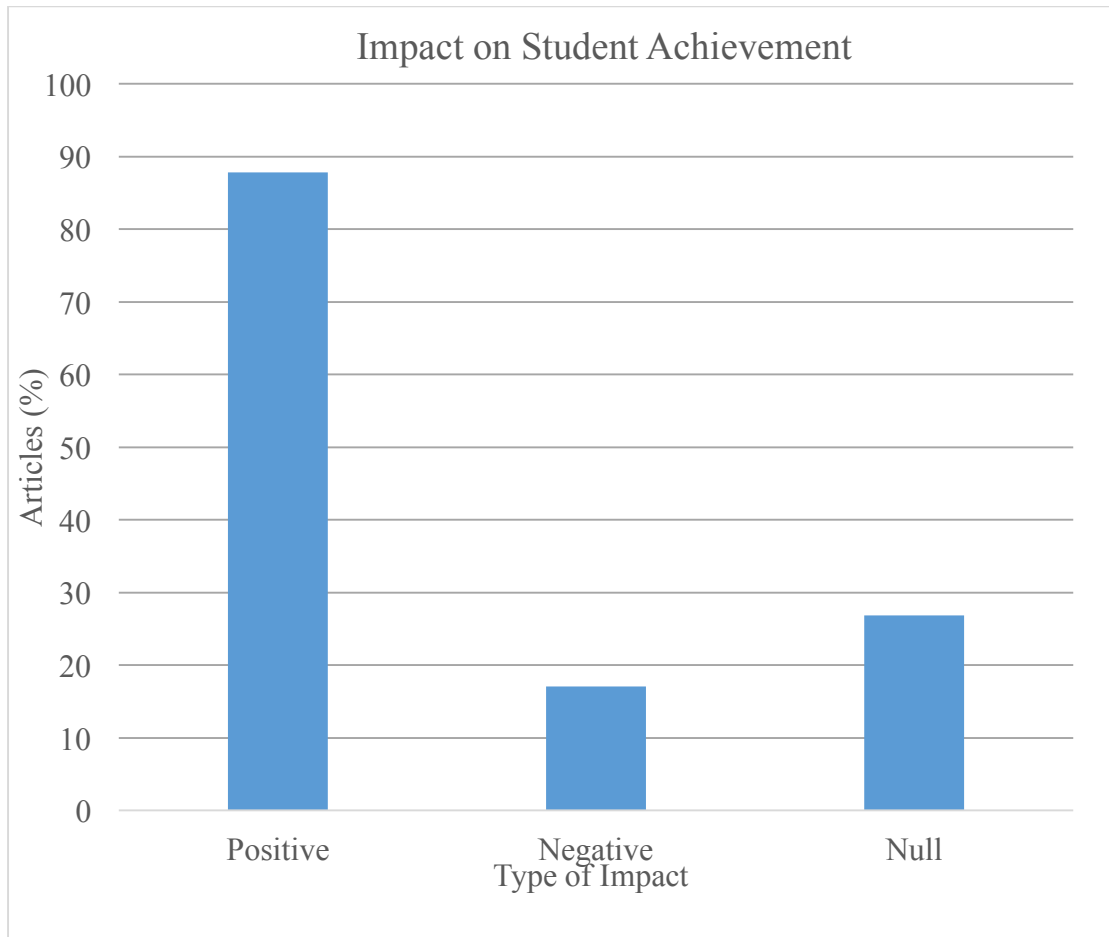


Figure 4.1. Impact on Student Achievement. This figure illustrates the percentage of articles that reported a positive, negative, or null impact on student achievement.

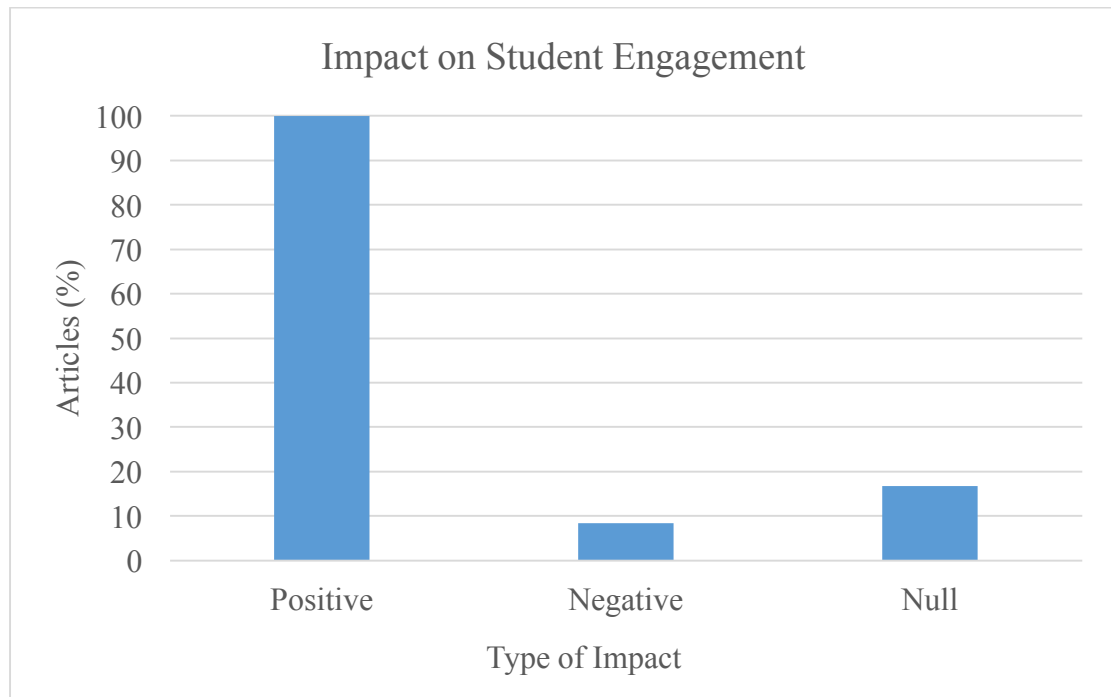


Figure 4.2. Impact on Student Engagement. This figure illustrates the percentage of articles that reported a positive, negative, or null impact on student engagement.

Other Factors of Learning

Of the 47 articles included in the data analysis, 21 (44.68%) reported effects on some other factor of learning (see Figure 4.3). Out of those, 16 (76.19%) articles found a positive effect on some other factor of learning. These other factors included: intent and expectation to finish high school, critical thinking skills, flexibility in teaching style, communication skills, retention of content, attitude towards using technology, increased responsibility for learning, more class time for student activities, ability to have a learner-centered approach to teaching, operational thinking, a positive attitude towards mathematics, being able to apply concepts in other areas, confidence in mathematics, ability to perform higher cognitively demanding tasks, higher-level thinking, improved feedback, increased attendance, decrease in behavioral issues, increase in independence, and ability to differentiate the learning.

Out of the 21 articles that reported effects on other factors, 8 (38.10%) reported a negative effect on some other factor of learning (see Figure 4.3). These other factors included: a perceived lack of benefit from the students, lack of visual and verbal queues resulting in a misunderstanding or miscommunication of intent or level of understanding, less favourable attitude towards classmates, time spent on demonstrating how to use the technology instead of student-led activities, decrease in motivation as time with the technology increases, technology used for low level tasks as a reward for finishing other tasks, technology delays and failures, and a negative attitudes towards computers.

Out of the 21 articles that reported effects on other factors, 5 (23.81%) reported a null effect on some other factor of learning (see Figure 4.3). These other factors included: the form of manipulative, the mode of play, performance avoidance,

type of activity, opinions on using computers, type of computer prompts, teacher's gender, teacher's level of education, student's gender, student's grade level, self-efficacy, type of mathematical problem, and attitude towards mathematics.

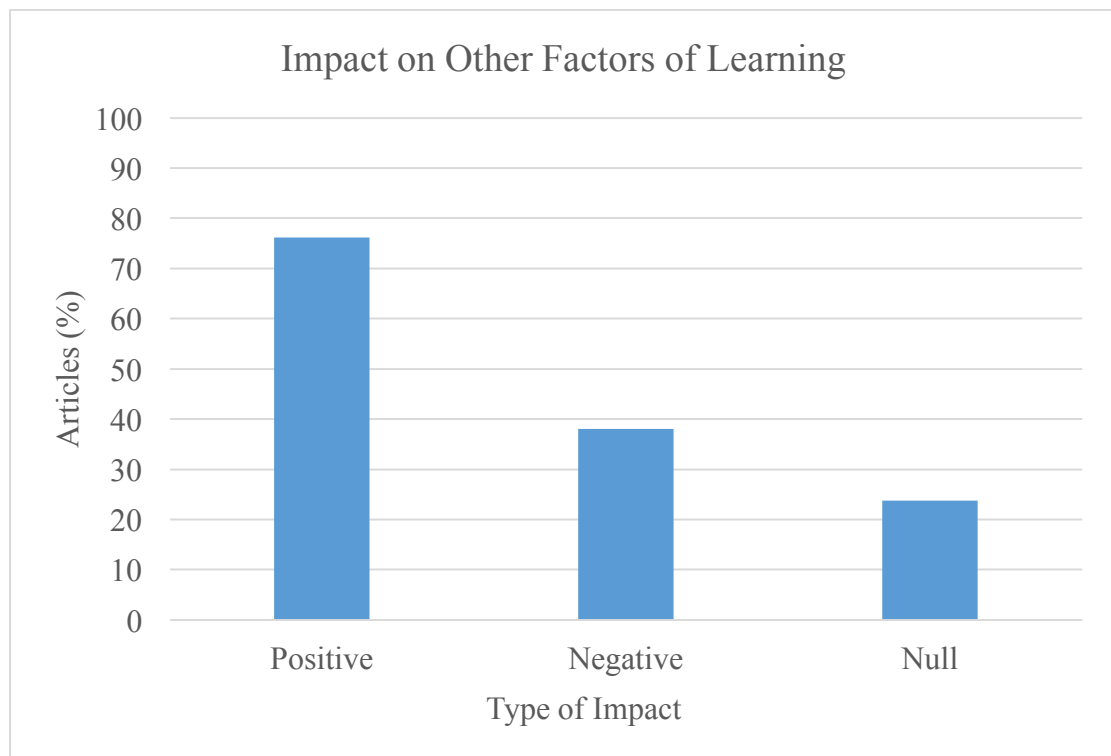


Figure 4.3. Impact on Other Factors of Learning. This figure illustrates the percentage of articles that reported a positive, negative, or null impact on other factors of learning.

Functionality of Digital Tools

In this study, *functionality* was defined as the operations, features, or capabilities that can be performed using the digital tool. These functions usually contribute to the interaction between the tool and the user. Through the first tier of the coding scheme, sections of text relating to the functions of the digital tool were macro-coded as ‘functionality.’ In the second tier of coding, these sections were copied into Excel and were used to create a list of reported operations, features, or capabilities. This list became the micro-codes with which each selection of text was analysed. Each article’s citation was used as a row heading and the list of micro-codes were used as column headings. This Excel spreadsheet was then used to record the functions reported within each article. If a function was not directly reported, it was not recorded, even if there was reason to believe that the function was present. Eleven articles were excluded during this process for not providing enough information on the functionality of the digital tool used (see Appendix C). The final spreadsheet was then analysed and compared to the findings of each article.

The list of micro-codes included: being user-friendly, having animations, having graphics or visuals, providing feedback, sharing the learning outcomes or goals explicitly, providing help or hints, showing the correct answer, being used to create content, the digital tool being mainly used for assessing skills, the ability to blog, access to spreadsheets, the digital tool being an immersive role playing game, providing a tutorial on the mathematical concept, the digital tool providing a game-based environment, providing rewards or incentives, the ability to draw, write, or highlight, providing a manipulative, having instructions provided by a virtual guide, the ability to message others through chat, email, or video conferencing, the ability to collaborate within the tool, having an avatar, the digital tool as a virtual world or

classroom, having a time limit, access to word processing software, access to presentation software, robotics, being adaptive to the user's ability level, providing a teacher dashboard, and the goal of the digital tool being linked directly to curriculum standards.

Each of the above micro-codes were then analysed according to the percentage of studies that reported it as a function of the digital tool in relation to the study's findings.

Student Achievement

Out of the 36 articles included in the functionality data analysis, 29 (80.56%) of the articles found a positive effect on student achievement, 2 (5.56%) of the articles found a negative effect on student achievement, and 8 (22.22%) of the articles found a null effect on student achievement. Out of the 29 articles that found a positive effect on student achievement, 13 (44.83%) of the articles reported the digital tool using graphics or visuals and 12 (41.38%) of the articles reported the digital tool providing feedback. Of the 6 articles that reported the digital tool using graphics or visuals and providing feedback, 5 of them reported on student achievement, and all 5 (100%) reported a positive effect on student achievement.

Each function was analysed by the percentage of articles that reported a positive effect on student achievement (see Table 4.1).

Table 4.1

Studies that Reported Positive Results on Student Achievement for Each Function

| Function | Total | Positive (%) |
|------------------------------|-------|--------------|
| Adaptive | 2 | 100 |
| Animation | 11 | 90.91 |
| Avatar | 3 | 100 |
| Blogging | 0 | - |
| Collaboration | 6 | 100 |
| Draw/Write/Highlight | 4 | 100 |
| Game-Based Environment | 8 | 100 |
| Graphics/Visuals | 13 | 100 |
| Hints/Help | 4 | 100 |
| Learning Outcomes Shared | 4 | 75 |
| Manipulative | 10 | 90 |
| Messaging | 6 | 83.33 |
| Presentation Software | 5 | 100 |
| Provides Feedback | 14 | 85.71 |
| Rewards/Incentives | 4 | 100 |
| Robotics | 1 | 100 |
| Role Playing Game | 3 | 66.67 |
| Shows Correct Answer | 5 | 60 |
| Spreadsheet | 1 | 100 |
| Students Create Content | 7 | 100 |
| Teacher Dashboard | 2 | 100 |
| Tied to Curriculum Standards | 7 | 100 |
| Time Limit | 2 | 50 |
| Tool is for Assessing Skills | 7 | 85.71 |
| Tutorial on Concept | 6 | 100 |
| User-Friendly | 3 | 100 |
| Virtual Guide | 1 | 100 |
| Virtual World/Classroom | 1 | 100 |
| Word Processing Software | 3 | 100 |

Note. The ‘Total’ column represents the number of articles that reported the aligned function. The ‘Positive’ column represents the percentage of the total articles that reported a positive effect on some aspect of student achievement.

The ‘functionality’ micro-codes were then analysed according to the percentage of articles that reported the micro-code and found a negative or null impact on student achievement subtracted from the percentage of articles that reported the micro-code and found a positive impact on student achievement (see Figure 4.4). In other words, if this calculation resulted in a big positive number, then the micro-code would have had a high percentage of articles finding a positive impact on some aspect of student achievement and a low percentage of articles reporting a null or negative impact on some aspect of student achievement. If this calculation resulted in a negative number, then the micro-code had a higher percentage of articles finding a null or negative impact on some aspect of student achievement than a positive impact on some aspect of student achievement. This does not, mean, however, that those micro-codes are detrimental to student achievement, as the article could report more than one finding.

The micro-codes used to represent students being able to use the tool to create content and the goal or objective of the digital tool being tied to curriculum standards were reported more than five times. Additionally, 100% of these articles report a positive impact on student achievement, and 0% of the articles report a null or negative impact on student achievement. The micro-codes that represent the tool showing the correct answer and the digital tool being a role-playing game resulted in a negative calculation. However, both micro-codes resulted in at least 60% of the articles finding a positive effect on some aspect of student achievement. Therefore, this contradiction could be a result of the small number of articles that reported these codes.

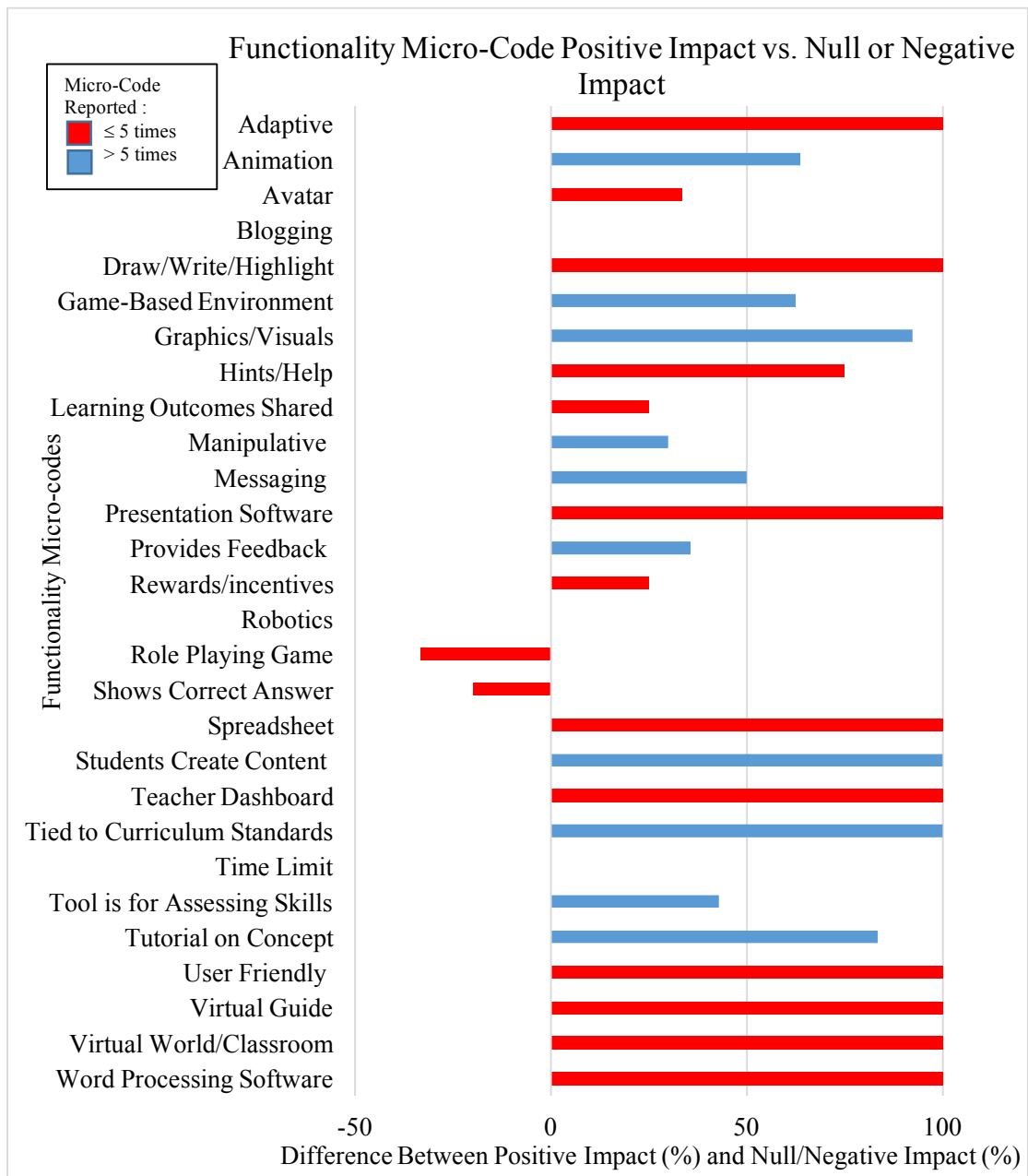


Figure 4.4. Functionality Micro-Code Positive Impact vs. Null or Negative Impact. This figure illustrates the difference between the percentage of articles that reported a positive impact and the percentage of articles that reported a null or negative impact for each micro-code. The blue bars represent the micro-codes that were reported more than five times.

Other Factors of Learning

Out of the 36 articles included in the functionality data analysis, 15 (41.67%) of the articles found a positive effect on other factors of learning, 7 (19.44%) of the articles found a negative effect on other factors of learning, and 4 (11.11%) of the articles found a null effect on other factors of learning. Out of the 15 articles that found a positive effect on other factors of learning, 7 (46.67%) of the articles reported the digital tool using animations, and 7 (46.67%) of the articles reported the digital tool providing manipulatives. Of the 6 articles that reported the digital tool both using animation and providing manipulatives, 5 of the articles reported on student achievement, and 4 (80.00%) of the articles found a positive effect on other factors of learning.

Each function was analysed by the percentage of articles that reported a positive effect on other factors of learning (see Table 4.2).

Table 4.2

Studies that Reported Positive Results on Other Factors of Learning for Each Function

| Function | Total | Positive (%) |
|------------------------------|-------|--------------|
| Adaptive | 0 | - |
| Animation | 8 | 87.5 |
| Avatar | 0 | - |
| Blogging | 1 | 100 |
| Collaboration | 3 | 66.67 |
| Draw/Write/Highlight | 2 | 100 |
| Game-Based Environment | 3 | 66.67 |
| Graphics/Visuals | 6 | 83.33 |
| Hints/Help | 1 | 0 |
| Learning Outcomes Shared | 2 | 50 |
| Manipulative | 8 | 87.50 |
| Messaging | 2 | 50 |
| Presentation Software | 4 | 75 |
| Provides Feedback | 7 | 57.14 |
| Rewards/Incentives | 1 | 0 |
| Robotics | 1 | 100 |
| Role Playing Game | 2 | 50 |
| Shows Correct Answer | 3 | 66.67 |
| Spreadsheet | 2 | 100 |
| Students Create Content | 4 | 75 |
| Teacher Dashboard | 2 | 100 |
| Tied to Curriculum Standards | 3 | 66.67 |
| Time Limit | 1 | 100 |
| Tool is for Assessing Skills | 3 | 33.33 |
| Tutorial on Concept | 3 | 66.67 |
| User-Friendly | 0 | - |
| Virtual Guide | 0 | - |
| Virtual World/Classroom | 0 | - |
| Word Processing Software | 3 | 66.67 |

Note. The 'Total' column represents the number of articles that reported the aligned function. The 'Positive' column represents the percentage of the total articles that reported a positive effect on other factors of learning.

Integration of Technology

In this study, *integration of technology* is defined as the instructional methods, pedagogy, or teaching strategies used to incorporate the use of technology or digital tools into curriculum, routines, or day-to-day practices. The first tier of the coding scheme had sections of text relating to the integration of technology be coded as ‘integration’. During the second tier of coding, these sections of text were copied into Excel and were used to create a list of the qualities of integration reported in the studies. This list became the micro-codes with which each selection of text was analysed. Excel was then used to chart the ‘integration’ micro-codes present within each article. If a quality was not directly reported, it was not recorded, even if there was reason to believe that the quality was present. Twelve articles were excluded for not providing enough information on the way the technology was integrated (see Appendix B). The final spreadsheet was then analysed and compared to the findings of each article.

The list of qualities of integration included: mathematical concepts being taught before or after students used the digital tool, use of the digital tool being connected to the current mathematical concepts being studied, feedback provided from the teacher, time to interact with the technology before the study, help with the mathematical concepts provided by the teacher or researcher, software or hardware support, no teacher participation or intervention, parent participation, professional development provided for the teachers, students being able to learn at their own pace, support for the teachers during integration, student-teacher conferences, teacher-facilitated learning of the mathematical concepts, ability for students to work collaboratively, and ability for students to work independently.

Each of the above qualities were then analysed according to the percentage of studies that reported it as a quality of the integration in relation to the study's findings.

Student Achievement

Out of the 35 articles included in the integration data analysis, 28 (80.00%) of the articles found a positive effect on student achievement, 2 (5.71%) of the articles found a negative effect on student achievement, and 9 (25.71%) of the articles found a null effect on student achievement. Out of the 28 articles that found a positive effect on student achievement, 20 (71.43%) of the articles reported the teacher facilitated the learning, 16 (57.14%) of the articles reported mathematical concepts were taught before or after using the digital tool, and 15 (53.57%) of the articles reported students having an opportunity to work collaboratively. Of the 9 articles that had the teacher facilitating the learning, mathematical concepts taught before or after using the technology, and an opportunity for students to work collaboratively, 8 of the articles reported on student achievement, and all 8 found a positive effect on some aspect of student achievement.

Each quality was analysed by the percentage of articles that reported a positive effect on student achievement (see Table 4.3).

Table 4.3

Studies that Reported Positive Results on Student Achievement for Each Quality

| Quality of Integration | Total | Positive (%) |
|---|-------|--------------|
| Concepts Taught Before and/or After | 19 | 84.21 |
| Connected to Concepts Being Studied | 10 | 90.00 |
| Feedback Provided from the Teacher | 5 | 80.00 |
| Had Time to Interact with the Technology Before Study | 7 | 85.71 |
| Help with Concepts Provided | 8 | 100.00 |
| Help with Software/Hardware | 9 | 77.78 |
| No Teacher Participation/Intervention | 8 | 87.50 |
| Parent Participation | 1 | 100.00 |
| Professional Development | 2 | 100.00 |
| Student - Teacher Conference | 1 | 100.00 |
| Students Learn at their Own Pace | 9 | 66.67 |
| Students Working Collaboratively | 16 | 93.75 |
| Students Working Independently | 14 | 78.57 |
| Support for Teachers During Integration | 3 | 100.00 |
| Teacher Facilitating the Learning | 21 | 95.24 |

Note. The 'Total' column represents the number of articles that reported the aligned quality. The 'Positive' column represents the percentage of the total articles that reported a positive effect on some aspect of student achievement.

The 'integration' micro-codes were then analysed according to the percentage of articles that reported the micro-code and found a negative or null impact on student achievement subtracted from the percentage of articles that reported the micro-code and found a positive impact on student achievement (see Figure 4.5). In other words, if this calculation resulted in a big positive number, then the micro-code would have had a high percentage of articles finding a positive impact on some aspect of student achievement and a low percentage of articles reporting a null or negative impact on some aspect of student achievement. If this calculation resulted in a negative number, then the micro-code had a higher percentage of articles finding a null or negative impact on some aspect of student achievement than a positive impact on some aspect of student achievement. Again, this does not mean that those micro-codes are detrimental to student achievement, as the article could report more than one finding.

The micro-codes used to represent the digital tool being connected the current mathematical concepts being studied, help with concepts provided, help with the software or hardware, and the teacher facilitating the learning were all reported more than 5 times and resulted in high positive numbers. Although the micro-codes that represented parent participation, professional development, student – teacher conferences, and support for teacher during integration were not reported more than 5 times, 100% of these articles report a positive impact on student achievement, and 0% of the articles report a null or negative impact on student achievement.

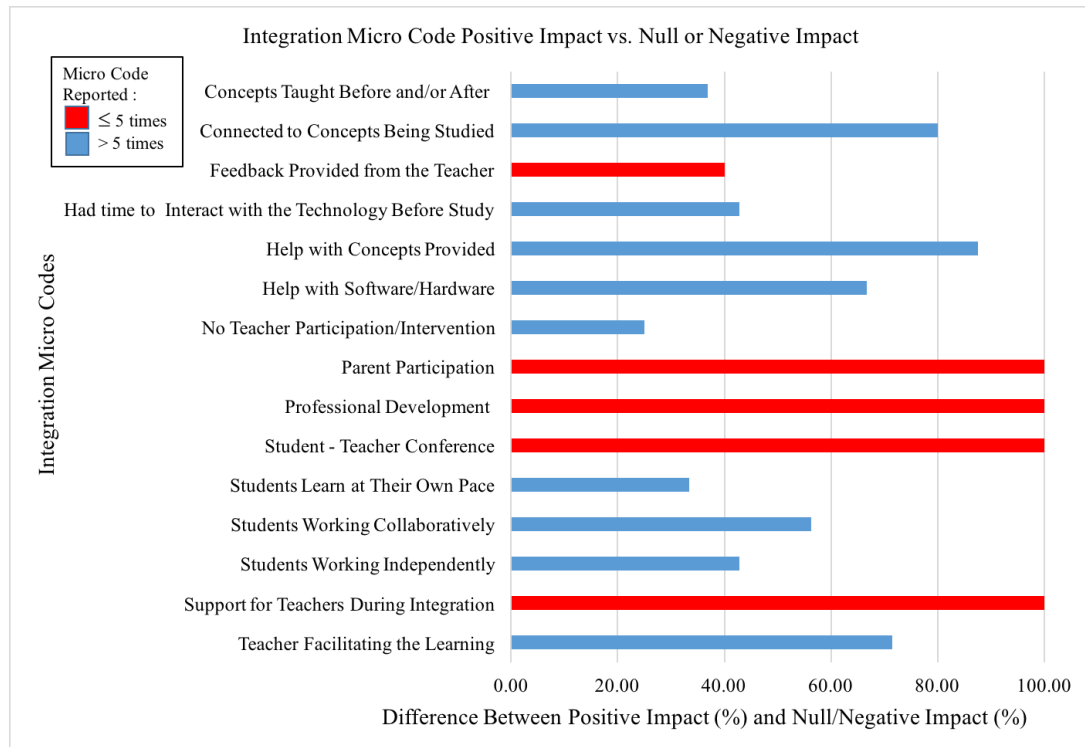


Figure 4.5. Integration Micro-Code Positive Impact vs. Null or Negative Impact. This figure illustrates the difference between the percentage of articles that reported a positive impact and the percentage of articles that reported a null or negative impact for each micro-code. The blue bars represent the micro-codes that were reported more than five times.

Other Factors of Learning

Out of the 35 articles included in the integration data analysis, 15 (42.86%) of the articles found a positive effect on other factors of learning, 7 (20.00%) of the articles found a negative effect on other factors of learning, and 5 (14.29%) of the articles found a null effect on other factors of learning. Out of the 15 articles that found a positive effect on other factors of learning, 13 (86.67%) of the articles teacher as the facilitator of learning, 8 (53.33%) of the articles reported that the use of the digital tool was connected to the current mathematical concept being studied, 8 (53.33%) of the articles had an opportunity for the student to work independently, 9 (60.00%) of the articles reported the mathematical concept was taught before or after using the digital tool, and 8 (53.33%) of the articles had an opportunity for the student to work collaboratively. Of the three articles that had the teacher as the facilitator of learning, the use of the digital tool was connected to the current mathematical concept being studied, the teacher provided an opportunity for the student to work independently and collaboratively, and the mathematical concept was taught before or after using the digital tool. All 3 (100%) of the articles reported a positive effect on some other factor of learning.

Each function was analyzed by the percentage of articles that reported a positive effect on other factors of learning (see Table 4.4).

Table 4.4

Studies that Reported Positive Results on Other Factors of Learning for Each Quality

| Function | Total | Positive (%) |
|---|-------|--------------|
| Concepts Taught Before and/or After | 11 | 81.82 |
| Connected to Current Concepts Being Studied | 8 | 100 |
| Feedback Provided from the Teacher | 2 | 100 |
| Had Time to Interact with the Technology Before Study | 3 | 33.33 |
| Help with Concepts Provided | 6 | 83.33 |
| Help with Software/Hardware | 4 | 75 |
| No Teacher Participation/Intervention | 5 | 40 |
| Parent Participation | 0 | - |
| Professional Development | 3 | 100 |
| Student - Teacher Conference | 1 | 100 |
| Students Learn at their Own Pace | 5 | 80 |
| Students Working Collaboratively | 11 | 72.73 |
| Students Working Independently | 9 | 88.89 |
| Support for Teachers During Integration | 3 | 100 |

Note. The 'Total' column represents the number of articles that reported the aligned quality. The 'Positive' column represents the percentage of the total articles that reported a positive effect on other factors of learning.

Ages of Study Participants

The age of the participants in each study was recorded in Excel 2016 (see Figure 4.6). Out of the 47 articles included in the data analysis, 21 (44.68%) of the articles used participants that were 10 years-old, 23 (48.94%) of the articles used participants that were 11 years-old, 16 (34.04 %) of the articles used participants that were 12 years-old, 15 (31.91%) of the articles used participants that were 13 years-old, 14 (29.79%) of the articles used participants that were 14 years-old, and 5 (10.64%) of the articles had participants that were elementary teachers.

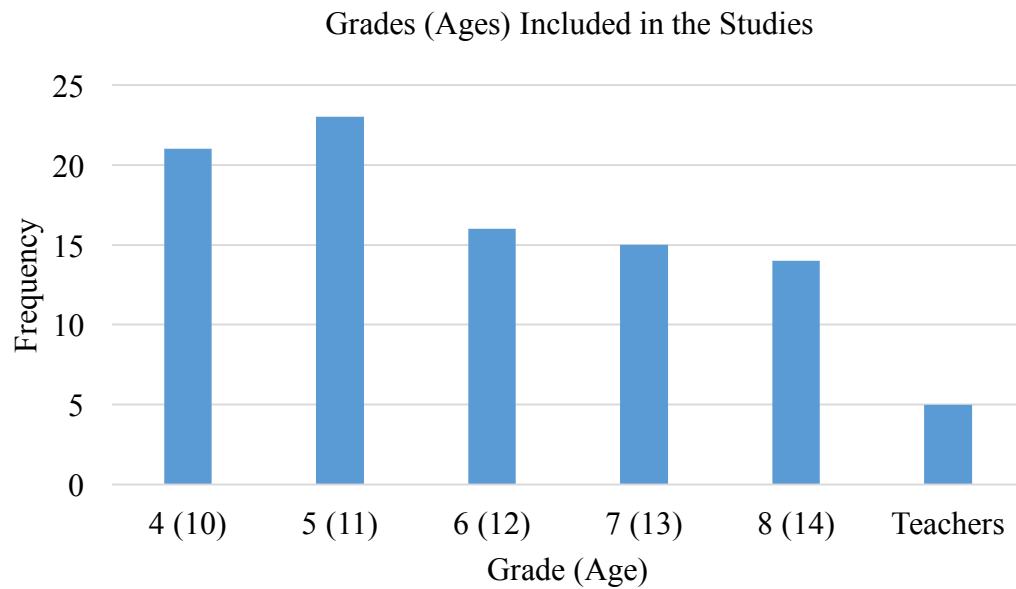


Figure 4.6. Grades (Ages) Included in the Studies. This bar graph shows the extent to which each age group is represented within the studies.

The findings presented in this chapter are the results of a meta-analysis of studies examining the impact of technology. Through a keyword search and exclusion criteria, a systematic collection of relevant articles was completed, followed by a two-tier coding scheme to analyse the findings. These findings will be used in order to examine the functionality of digital tools and the integration of those digital tools that most impact student achievement and student engagement. The next chapter will discuss these findings, their place in literature, and the researcher's interpretation of the results.

CHAPTER FIVE: SUMMARY, DISCUSSION, AND RECOMMENDATIONS

Due to research linking the use of educational technology to higher student achievement and engagement, more and more schools are allocating money towards improving the use of technology in the classroom (Tamom, 2011; Toronto District School Board, 2015). Therefore, there is a push for educators to use the new technology purchased by the school boards. However, teaching mathematics with technology requires educators to be proficient in a large number of competencies (Bennison & Goos, 2010; Jarvis, 2016; NCTM, 2015; Thomas & Hong, 2012). Educators need to have an understanding of how to use technology within a classroom, have a strong understanding of how to teach mathematics, value the use of technology, and build their confidence with using technology in mathematics (Thomas & Hong, 2012).

However, a lot of professional development opportunities offered to teachers on the use of technology focus on specific products and their functionality, rather than the pedagogy behind using technology and how to best integrate it into the classroom (Bennison & Goos, 2010). This lack of knowledge leads to educators forcing technology into traditional teacher-focused teaching methods, resulting in the ineffective integration of the purchased educational technology (Kinchin, 2012).

Therefore, the purpose of this study was to deconstruct articles that examine the effect of technology on student achievement, student engagement, and other factors of learning within elementary mathematics to determine the functions of digital tools and the qualities of technology integration that most impact student learning. It is my hope that the findings of this analysis help educators to effectively evaluate and integrate educational technology to increase its potential impact on student achievement and engagement. In addition, I hope that the findings of this

study increase the number of effective professional development opportunities available to educators and encourage educational technology companies to design products with education pedagogy in mind.

Summary of the Study

This study consisted of two keyword searches in Academic Search Complete, resulting in 467 different articles. The abstracts from these articles were then copied into Excel 2016 and filtered using exclusion and inclusion criteria, resulting in a total of 47 relevant articles. After implementing a two-tier coding scheme using QDA Miner 4 Lite, Excel 2016, and Word 2016, spreadsheets on the age of the participants, the findings, and the functionality and integration of technology were created, analysed, and compared.

Overall, the study found that 87.80% of articles that reported on student achievement found that the use of educational technology had a positive effect on some aspect of student achievement. Additionally, 100% of the articles that reported on student engagement found that the use of educational technology had a positive effect on some aspect of student engagement. Finally, 79.19% of the articles that reported on other factors of learning found that the use of educational technology had a positive effect on some other factor of learning.

In terms of functionality, studies found a positive effect on some aspect of student achievement or other factor of learning if the digital tool

- was adaptive,
- allowed for collaboration,
- allowed the use of an avatar,
- used blogging tools,
- provided the opportunity to draw, write, or highlight,

- used a game-based environment,
- had graphics and visuals,
- provided hints or help,
- provided instructions through a virtual guide,
- used presentation software,
- provided awards or incentives,
- used robotics,
- used spreadsheets,
- allowed users to create content,
- provided a teacher dashboard,
- linked to curriculum standards,
- provided tutorials on the concepts,
- was user-friendly,
- used a virtual world or classroom, or
- used word processing software.

However, some of these qualities were reported a limited number of times, or also found negative or null findings on student achievement. Interestingly, the micro-codes representing the digital tool allowing the students to create the content or the goal of the digital tool being connected to curriculum standards were reported more than five times each, with 100% of the articles reporting a positive effect on student achievement and 0% of the articles reporting a negative or null effect on student achievement.

In terms of integration, studies found a positive effect on student achievement or some other factor of learning if the integration of the digital tool

- was connected to current mathematical concepts being studied,

- provided feedback from the teacher,
- allowed the educator to provide help with the concepts,
- included parent participation,
- provided professional development opportunities,
- included student-teacher conferences, or
- provided support for the teachers during integration.

Although the micro-codes for parent participation, professional development opportunities, student-teacher conferences, and support for teachers during integration were not reported more than 5 times, all four of them had 100% of the articles report a positive effect on student achievement, and 0% of the articles report a negative effect on student achievement.

In terms of the age of participants included in the studies, all ages 10 to 14 were represented within the studies, as well as some studies using elementary teachers as participants.

Discussion

The Impact of Technology on Student Achievement, Student Engagement and Other Factors of Learning

Research has shown that the use of technology has the potential to enhance mathematics teaching and learning (NCTN, 2015; Ontario Ministry of Education, 2005; Small, 2012). Therefore, it is not surprising that 76.19% of the articles that reported on factors of learning such as communication skills, content retention, teaching strategies, and higher-order thinking found that technology had a positive impact. Additionally, due to already extensive research in this area, it was not surprising that 100% of the articles that reported on student engagement found

technology to have a positive impact (Bray & Tangney, 2016; Cicconi, 2014; Eyyam & Yaratan, 2014; Schibeci et al., 2008; Zepke & Leach, 2012).

However, it was surprising to find that 87.80% of the articles that reported on student achievement found technology had a positive effect on some aspect of student achievement. Research has shown that technology has the potential to positively impact student achievement (Bray & Tangney, 2016; Carini et al., 2006; Carr, 2012; Carrasco & Torrecilla, 2012; Cicconi, 2014; Eyyam & Yaratan, 2014; Marks, 2000; Schibeci et al., 2008), but several studies also reported finding a null or negative impact (Carr, 2012; Carrasco & Torrecilla, 2012). Therefore, I was expecting a much lower percentage of studies to find a positive effect on student achievement.

Therefore, this study further supported the research that the use of technology within the mathematics classroom has a high degree of potential to positively impact student achievement, student engagement, and other factors of learning.

Functionality of Digital Tools

According to previous research, the digital tool's environment should be engaging, use gaming characteristics, allow user control, freedom, or personalization, be consistent in language, provide visible or retrievable instructions, allow for collaboration, and be user- friendly (Lee & Cherner, 2015; Schibeci et al., 2008; Squires & Preece, 1999). This study supported these findings with the fact that 100% of the articles that used a game-based environment, took place in a virtual world, used a personalized avatar, provided rewards, gave simple instructions through the use of a virtual guide, allowed for collaboration, or was user-friendly found a positive effect on some aspect of student achievement, and over 50% of these articles also had a positive effect on some other factor of learning.

In terms of the visual presentation of the digital tool, it should use various forms of media, be visually appealing with a simple design, and be engaging (Lee & Cherner, 2015; Schibeci et al., 2008; Squires & Preece, 1999). This study supported these findings with the fact that over 90% of the articles that used animations, graphics, and visuals found a positive impact on student achievement, and over 80% of the articles also found a positive effect on some other factor of learning.

The purpose of the digital tool is a major predictor of the potential impact the tool can have. According to research, the digital tool should focus on teaching for concept recognition, explore concepts, develop higher-order thinking skills, and develop 21st century skills rather than information recall, as well as have the ability to link to other platforms (Lee & Cherner, 2015; Schibeci et al., 2008; Squires & Preece, 1999). This study supported this research, showing that over 80% of articles where the digital tool allowed for content creation and linked with other platforms such as word-processing software, presentation software, or spreadsheets, as well as tools such as blogging or instant messaging, found a positive impact on student achievement, and over 50% also found a positive effect on some other factor of learning. To add to current research, this study also found that over 90% of the articles where the digital tool allowed students to manipulate objects within the tool and provide input through drawing, writing, or highlighting had a positive impact on student engagement, and over 85% of the articles also found a positive impact on some other factor of learning.

In terms of the digital tool's connection to education pedagogy, research shows that the digital tool should contain a teacher dashboard for educators to monitor students' progress, provide hints and help to the students, provide tutorials on concepts, share learning goals, provide assistance to reach the correct answer, have a

real world connection and be tied to curriculum, provide feedback, differentiate to user's ability level or be adaptive, and allow users to move at their own pace (Lee & Cherner, 2015; Schibeci et al., 2008; Squires & Preece, 1999). This study supported this research, showing that over 60% of the articles that had one or more of those qualities found a positive effect on student achievement, and over 50% also found a positive effect on some other factor of learning.

Perhaps the most intriguing result that was not previously discovered in research was that 100% of the articles that used digital tools that were adaptive, allowed students to provide input through drawing, writing, or highlighting, provided instructions through a virtual guide, used creation software such as presentation software, word-processing software, or spreadsheets, had a teacher dashboard, were user-friendly, and provided a virtual world or classroom found a positive impact on student achievement and 0% found a null or negative impact on student achievement. However, each of these micro-codes was not reported more than five times. Therefore, more research would need to be done to ensure that this pattern continued. On the other hand, micro-codes that represented digital tools that allowed students to create content or be connected to curriculum standards were reported more than five times, also resulting in 100% of the articles finding a positive impact on student achievement and 0% of the articles finding a null or negative impact. Therefore, it can be interpreted that the functions that have the most positive impact on student achievement and other factors of learning are the digital tool being connected to curriculum or learning goals and the tool allowing users to create and explore concepts, rather than merely focusing on the recall of information.

All in all, digital tools that have an engaging environment, use gaming characteristics, allow for user personalization such as through an avatar, provide easy

retrievable or understandable instructions such as through a virtual guide, and are user-friendly were more likely to have a positive impact on students. Additionally, the digital tool should be visually appealing and use multiple types of media that is in a simple design. Plus, the tool should focus on allowing users to create content, explore concepts, or manipulate concepts while connecting to other platforms to develop higher-order thinking and 21st century skills. Finally, it should provide a teacher dashboard, be connected to the real world, the learning goals and the curriculum, and provide feedback and assistance in the process to find the correct answer. It should also allow for collaboration and allow users to move at their own pace and challenge level.

Technology Integration

The use of technology within the classroom can be daunting due to a lack of confidence to transition from traditional teaching methods to technology-enhanced methods (Jarvis, 2016). However, the process of planning a lesson with the use of technology is similar to that of any other teaching strategy (Campe, 2011; Wiggins & McTighe, 2006). Just like any other teaching strategy, educators must have effective professional development opportunities to build on their pedagogical knowledge of teaching and learning, as well as workshops that push beyond the *show-and-tell* type of activities to provide information on how mathematics pedagogy can be aligned and enhanced using technology (Anthony & Walshaw, 2009; Bennison & Goos, 2010; Bruce et al., 2010; Ontario Ministry of Education, 2011). Even after all of this research, out of the 35 articles included in the integration analysis of this study, only 2 (5.71%) of the articles had professional development opportunities for the educators prior to use with the digital tool, and only 3 (8.57%) of the articles had support for the teachers during the integration process. However, all of the studies (100%) that had

professional development opportunities or support for the teachers during integration found a positive impact on student achievement and other factors of learning and no null or negative impact.

Additionally, educators should spend time getting to know all the functions available within the digital tool, allow students to interact with the tool prior to use within a lesson, and allow students to explore within the tool (Campe, 2011). In this study, over 75% of the studies that allowed students time to interact with the tool prior to the lesson and provided help with the tool during the lesson found the digital tool had a positive impact on student achievement. This could be due to the fact that prior exploration may reduce time spent on technology-related questions, as well as behavior problems due to the novelty aspect.

It is important for mathematics education to take on a problem-based learning environment where students can construct their own knowledge and conceptual understanding through authentic, engaging opportunities based in a real-world context (Anthony & Walshaw, 2009; Jarvis, 2016; Ontario Ministry of Education, 2005; Small, 2012). The use of technology within the mathematics classroom does not take away from the pedagogical decisions that educators need to make in order to most benefit student success. Therefore, the use of technology within the classroom should take on a blended format of learning within or through the use of digital tools alongside learning through face-face interactions (Campe, 2011; Delgado et al., 2015). Educators should clarify expectations, provide help with concepts, design activities to build understanding, scaffold learning, assess understanding, and provide opportunities for collaborative and independent learning (Campe, 2011; Wiggins & McTighe, 2006). In fact, even though the micro-code that represented studies where there was no teacher intervention or participation was reported more than 5 times, it

received the lowest difference in percentage of studies finding a positive impact on student engagement versus a null or negative impact. Furthermore, over 80% of the studies that reported having the teacher as a facilitator, the concepts being taught before or after use of the digital tool, help with the concepts provided by the teacher, feedback provided from the teacher, or the purpose of the digital tool being aligned to the current mathematics being studied found a positive impact on student achievement, and over 80% of the studies also found a positive effect on other factors of learning.

Most importantly, the finding that was not previously discovered in research was that 100% of the studies that had parent participation or student-teacher conferences found a positive impact on student achievement, and 0% of the studies found a null or negative impact. However, both qualities were reported less than five times, so more research will need to be done before a general statement can be made.

All in all, professional development opportunities and support for teachers needs to be provided before, during, and after integration of technology. Furthermore, educators and students need time prior to the lesson to become familiar with the digital tools and its available functions. Finally, educators need to apply their pedagogical knowledge to the concepts and align it to the digital tools that can enhance those strategies, such as whether work is best done collaboratively or independently, if there is an opportunity for parental involvement, or if student-teacher conferences are beneficial. It should be introduced in a blended format with the teacher as a facilitator, teaching concepts in alignment with the tool so that it is connected to the curriculum, feedback can be provided, and assistance with concepts can be available.

Implications and Recommendations

Implications for Practice

At first, it may seem as though the findings within this paper only support what was already known in research. However, there is a significant gap between what is being found in research and what is being experienced within teaching practice today. It remains that out of the 35 articles included in the integration analysis of this study, only 2 of the articles had professional development opportunities available for the educators prior to use with the digital tool, and only 3 of the articles had support for the teachers during the integration process. This is surprising due to the large amount of research pushing for more professional development opportunities. Additionally, 12 studies (25.53%) could not be included in the integration analysis because there was not enough information written in the article to suggest how the digital tool was used within the classroom, and 11 studies (23.40%) could not be included in the functionality analysis because no details were given about the functions available within the digital tool. It is important to remember that this meta-analysis is limited by the information provided by the authors of the included studies. This means that aspects of functionality or qualities of integration may have been present in the study, but not reported in the research paper. However, it highlights a need for there to be stronger link between research and current teaching practice.

It is my hope that the research within this study helps to strengthen this connection so that educators can apply theory to practice within their classroom, increasing the potential for educational technology to have a positive impact on student engagement and achievement in their elementary mathematics classrooms. Additionally, school leaders can see a tangible reason for a greater number of

effective professional development opportunities and support for teachers before, during, and after the integration process. Finally, educational technology companies can use this information to help them focus on developing educational tools with teaching pedagogy in mind.

Recommendations

To further the link between theory and practice, all the research examined within this study, in addition to my findings and personal experience, were used to create The Bunz Model of Technology Evaluation and Integration described in my book, *How to Integrate and Evaluate Educational Technology* (2016), which can be found at <http://bit.ly/bunzbook>. Additionally, a video to further disseminate this research can be found at <http://bit.ly/mrpvideo>.

Concluding Thoughts

In his book *Democracy and Education*, John Dewey (1944) wrote, “if we teach children the same way today that we did yesterday, we rob them of tomorrow” (p. 167). Similarly, if educators want to prepare 21st century students for an information and technology-based society, using technology in the classroom is essential. This can be seen as a difficult, complex task. However, through effective professional development opportunities, support for teachers during integration, and effective evaluation and integration techniques, educational technology can have a significant positive impact on student achievement, engagement, and other factors of learning.

References¹

- Anthony, G. & Walshaw, M. (2009). Effective pedagogy in mathematics.
International Bureau of Education, Educational Practice Series, 19. Retrieved
 from:
http://www.ibe.unesco.org/fileadmin/user_upload/Publications/Educational_Practices/EdPractices_19.pdf
- *Afzal, M. T. & Gondal, M. B. (2010). Effect of mathematics software facilitated teaching on students' learning. *International Journal of Technology, Knowledge & Society, 6*(3), 111-120.
- Axelson, R. D. & Flick, A. (2010). Defining student engagement. *Change: The Magazine of Higher Learning, 43*(1), 38-43.
<http://doi.org/10.1080/00091383.2011.533096>
- *Ball, C., Huang, K., Cotten, S. R., Rikard, R. & Coleman, L. O. (2016). Invaluable values: An Expectancy-value theory analysis of youths' academic motivations and intentions. *Information, Communication & Society, 19*(5), 618-638.
[doi:10.1080/1369118X.2016.1139616](https://doi.org/10.1080/1369118X.2016.1139616)
- *Barzilai, S. & Blau, I. (2014). Scaffolding game-based learning: Impact on learning achievements, perceived learning, and game experiences. *Computers & Education, 70*65-79. [doi:10.1016/j.compedu.2013.08.003](https://doi.org/10.1016/j.compedu.2013.08.003)
- Bennison, A. & Goos, M. (2010). Learning to teach mathematics with technology: A Survey of professional development needs, experiences and impacts. *Mathematics Education Research Journal, 22*(1), 31-56.
<http://doi.org/10.1007/BF03217558>

¹ References marked with an asterisk indicate studies included in the meta-analysis.

- Bingimlas, K. A. (2009). Barriers to the successful integration of ICT in teaching and learning environments: A Review of the literature. *Eurasia Journal of Mathematics, Science and Technology Education*, 5(3), 235–245.
<http://doi.org/10.1103/PhysRevA.71.032327>
- Blake, C. T., Davies, C., Jones, A., Morris, E. & Scanlon, E. (2003). Evaluating complex digital resources. *Research in Learning Technology*, 11(1), 4–16.
<http://doi.org/http://dx.doi.org/10.3402/rlt.v11i1.11263>
- Bray, A. & Tangney, B. (2015). Enhancing student engagement through the affordances of mobile technology: A 21st century learning perspective on realistic mathematics education. *Mathematics Education Research Journal*, 28(1), 173–197. <http://doi.org/10.1007/s13394-015-0158-7>
- Bruce, C., Esmonde, I., Ross, J., Dookie, L. & Beatty, R. (2010). The Effects of sustained classroom-embedded teacher professional learning on teacher efficacy and related student achievement. *Teacher and Teacher Education*, 26(1), 1598–1608.
- *Cakir, O. & Simsek, N. (2010). A comparative analysis of the effects of computer and paper-based personalization on student achievement. *Computers & Education*, 55(4), 1524-1531. doi:10.1016/j.compedu.2010.06.018
- Campe, K. D. (2011). Do it right: Strategies for implementing technology. *The Mathematics Teacher*, 104(8), 620–625.
- Card, N. A. & Little, T. D. (2012). Applied meta-analysis for social science research. [Electronic resource]. New York: Guilford Press, c2012.
- Carini, R. M., Kuh, G. D. & Klein, S. P. (2006). Student engagement and student learning: Testing the linkages. *Research in Higher Education*, 47(1), 1–32.
<http://doi.org/10.1007/s11162-005-8150-9>

- *Carr, J. M. (2012). Does math achievement h'APP'en when iPads and game-based learning are incorporated into fifth-grade mathematics instruction?. *Journal of Information Technology Education*, 11, 269-286.
- *Carrasco, M. R. & Torrecilla, F. J. M. (2012). Learning environments with technological resources: A Look at their contribution to student performance in Latin American elementary schools. *Educational Technology Research and Development*, 60(6), 1107–1128. <http://doi.org/10.1007/s11423-012-9262-5>
- *Chang, K., Wu, L., Weng, S. & Sung, Y. (2012). Embedding game-based problem-solving phase into problem-posing system for mathematics learning. *Computers & Education*, 58(2), 775-786.
doi:10.1016/j.compedu.2011.10.002
- Chemali, J. (2016, January 15). Blend like a boss: Tips, tricks and resources for effective blended learning. Workshop presented at the Future of Educational Technology Conference, Orlando, Florida.
- Cicconi, M. (2014). Vygotsky meets technology: A Reinvention of collaboration in the early childhood mathematics classroom. *Early Childhood Education Journal*, 42(1), 57–65. <http://doi.org/10.1007/s10643-013-0582-9>
- Cotabish, A., Dailey, D., Robinson, A. & Hughes, G. (2013). The Effects of a STEM intervention on elementary students' science knowledge and skills. *School Science & Mathematics*, 113(5), 215-226. doi:10.1111/ssm.12023
- Delgado, A., Wardlow, L., O'Malley, K. & McKnight, K. (2015). Educational technology: A Review of the integration, resources, and effectiveness of technology in K-12 classrooms. *Journal of Information Technology Education: Research*, 14, 397–416.

- Dewey, J. (1944). *Democracy and education*. New York: Macmillan Company.
- Drake, S. M. (2007). *Creating standards-based integrated curriculum*. Thousand Oaks, California: Corwin Press/Sage Publications Ltd.
- EBSCO Industries. (2016a). Academic Search Complete. Retrieved from <https://www.ebscohost.com/academic/academic-search-complete>
- EBSCO Industries. (2016b). ERIC. Retrieved from <https://www.ebscohost.com/academic/eric>
- *Erbas, A. K., & Yenmez, A. A. (2011). The Effect of inquiry-based explorations in a dynamic geometry environment on sixth grade students' achievements in polygons. *Computers & Education*, 57(4), 2462-2475.
doi:10.1016/j.compedu.2011.07.002
- Eyyam, R. & Yaratan, H. S. (2014). Impact of use of technology in mathematics lessons on student achievement and attitudes. *Social Behavior & Personality: An International Journal*, 42, 31–42. <http://doi.org/10.2224/sbp.2014.42.0.S31>
- *Falkenberg, C. & Barbetta, P. (2013). The Effects of a self-monitoring package on homework completion and accuracy of students with disabilities in an inclusive general education classroom. *Journal of Behavioral Education*, 22(3), 190-210. doi:10.1007/s10864-013-9169-1
- Fredricks, J. A, Blumenfeld, P. C. & Paris, A. H. (2004). School engagement: Potential of the concept, State of the evidence. *Review of Educational Research*, 74(1), 59–109. <http://doi.org/10.3102/00346543074001059>
- Green, L. S. (2014). Through the looking glass: Examining technology integration in school librarianship. *Knowledge Quest*, 43(1), 36–43.

- Guerrero, S. (2010). Technological pedagogical content knowledge in the mathematics classroom. *Journal of Digital Learning in Teacher Education*, 26(4), 132–139. <http://doi.org/10.1080/10402454.2010.10784646>
- *Haltiwanger, L., Horton, R. M. & Lance, B. (2014). Using technology to build a pen for browser. *Mathematics Teaching in The Middle School*, 20(1), 46-50.
- Harris, L. R. (2008). A Phenomenographic investigation of teacher conceptions of student engagement in learning. *The Australian Educational Researcher*, 35(1), 57–79. <http://doi.org/10.1007/BF03216875>
- Hegedus, S. J., Tapper, J. & Dalton, S. (2014). Exploring how teacher-related factors relate to student achievement in learning advanced algebra in technology-enhanced classrooms. *Journal of Mathematics Teacher Education*, 19(1), 7–32. <http://doi.org/10.1007/s10857-014-9292-5>
- *House, J. D. & Telese, J. A. (2011). Effects of computer activities and classroom lesson strategies on motivation for mathematics learning for eighth-grade students in the United States and Korea. *International Journal of Instructional Media*, 38(3), 295-306.
- *House, J. D. & Telese, J. A. (2012). Effects of mathematics lesson activities and computer use on algebra achievement of eighth-grade students in the United States and Japan: Findings from the TIMSS 2007 assessment. *International Journal Of Instructional Media*, 39(1), 69-81.
- *Hrastinski, S., Edman, A., Andersson, F., Kawnine, T. & Soames, C. (2014). Informal math coaching by instant messaging: Two case studies of how university students coach K-12 students. *Interactive Learning Environments*, 22(1), 84-96. [doi:10.1080/10494820.2011.641682](http://doi.org/10.1080/10494820.2011.641682)

- *Hwang, W. & Hu, S. (2013). Analysis of peer learning behaviors using multiple representations in virtual reality and their impacts on geometry problem solving. *Computers & Education*, 62, 308-319.
doi:10.1016/j.compedu.2012.10.005
- *Jackson, A., Brummel, B., Pollet, C. & Greer, D. (2013). An Evaluation of interactive tabletops in elementary mathematics education. *Educational Technology Research & Development*, 61(2), 311-332. doi:10.1007/s11423-013-9287-4
- *Jang, S. & Tsai, M. (2012). Exploring the TPACK of Taiwanese elementary mathematics and science teachers with respect to use of interactive whiteboards. *Computers & Education*, 59(2), 327-338.
doi:10.1016/j.compedu.2012.02.003
- Jarvis, D. (2016). Messy but meaningful: Exploring the transition to reform-based pedagogy with teachers of mathematics and coordinators in Ontario, Canada. *Teacher Development*, 20(1), 18–39.
<http://dx.doi.org/10.1080/13664530.2015.1108928>
- Joint Mathematical Council of the United Kingdom. (2011). Digital technologies and mathematics education. Retrieved from
https://www.ncetm.org.uk/files/9793653/JMC_Digital_Technologies_Report_2011.pdf
- *Kanive, R., Nelson, P. M., Burns, M. K. & Ysseldyke, J. (2014). Comparison of the effects of computer-based practice and conceptual understanding interventions on mathematics fact retention and generalization. *Journal of Educational Research*, 107(2), 83-89. doi:10.1080/00220671.2012.759405

- *Karatas, I. (2014). Changing pre-service mathematics teachers' beliefs about using computers for teaching and learning mathematics: the effect of three different models. *European Journal of Teacher Education*, 37(3), 390-405.
doi:10.1080/02619768.2013.870993
- *Kim, C., Kim, D., Yuan, J., Hill, R. B., Doshi, P. & Thai, C. N. (2015). Robotics to promote elementary education pre-service teachers' STEM engagement, learning, and teaching. *Computers & Education*, 91, 14-31.
doi:10.1016/j.compedu.2015.08.005
- Kinchin, I. (2012). Avoiding technology-enhanced non-learning. *British Journal of Educational Technology*, 43(2), 43–49. <http://doi.org/10.1111/j.1467-8535.2011.01264.x>
- *Kiriakidis, P. P. & Geer, B. T. (2014). The Effect of success maker software on state scores in elementary school math. *Romanian Journal for Multidimensional Education / Revista Romaneasca Pentru Educatie Multidimensionala*, 6(2), 127-138.
- *Kiriakidis, P. P. & Johnson, T. (2015). Program evaluation: Integration of educational software into the elementary school math curriculum. *Romanian Journal for Multidimensional Education / Revista Romaneasca Pentru Educatie Multidimensionala*, 7(2), 55-65. doi:10.18662/rrem/2015.0702.05
- Koehler, M. (2011). What is TPACK?. Retrieved from <http://www.tpack.org/>
- Koehler, M. J. & Mishra, P. (2008). Introducing TPACK. In *Handbook of Technological Pedagogical Content Knowledge TPCK for Educators* (pp. 3–29). <http://doi.org/10.1080/17439884.2011.549829>

- *Kong, S. C. (2011). An Evaluation study of the use of a cognitive tool in a one-to-one classroom for promoting classroom-based dialogic interaction. *Computers & Education*, 57(3), 1851-1864. doi:10.1016/j.compedu.2011.04.008
- *Lee, C. Y. & Chen, M. J. (2015). Effects of worked examples using manipulatives on fifth graders' learning performance and attitude toward mathematics. *Educational Technology and Society*, 18(1), 264–275.
- Lee, C. Y. & Cherner, T. S. (2015). A Comprehensive evaluation rubric for assessing instructional apps. *Journal of Information Technology Education: Research*, 14(1), 21–53.
- Lee, N. H. & Ferrucci, B. J. (2012). Enhancing learning of fraction through the use of virtual manipulatives. *The Electronic Journal of Mathematics and Technology*, 6(2), 126 – 140.
- *Li, Q. & Ma, X. (2010). A Meta-analysis of the effects of computer technology on school students' mathematics learning. *Educational Psychology Review*, 22(3), 215–243. <http://doi.org/10.1007/s10648-010-9125-8>
- *Luzón, J. M. & Letón, E. (2015). Use of animated text to improve the learning of basic mathematics. *Computers & Education*, 88, 119-128.
doi:10.1016/j.compedu.2015.04.016
- Marks, H. M. (2000). Student engagement in instructional activity: Patterns in the elementary, middle, and high school years. *American Educational Research Journal*, 37(1), 153 – 184.
- Muir, T., Callingham, R. & Beswick, K. (2016). Using the IWB in an early years mathematics classroom: An Application of the TPACK framework. *Journal of Digital Learning in Teacher Education*, 32(2), 63–72.
<http://doi.org/10.1080/21532974.2016.1138913>

National Center for Education Statistics. (2002). *Chapter 7: Technology integration,*

technology in schools: Suggestions, tools, and guidelines for assessing

technology in elementary and secondary education. Retrieved from

http://nces.ed.gov/pubs2003/tech_schools/chapter7.asp

NCTM (2015). *Strategic use of technology in teaching and learning mathematics.*

Retrieved from [http://www.nctm.org/Standards-and-Positions/Position-](http://www.nctm.org/Standards-and-Positions/Position-Statements/Strategic-Use-of-Technology-in-Teaching-and-Learning-Mathematics/)

[Statements/Strategic-Use-of-Technology-in-Teaching-and-Learning-](http://www.nctm.org/Standards-and-Positions/Position-Statements/Strategic-Use-of-Technology-in-Teaching-and-Learning-Mathematics/)

[Mathematics/](http://www.nctm.org/Standards-and-Positions/Position-Statements/Strategic-Use-of-Technology-in-Teaching-and-Learning-Mathematics/)

*Nugent, G., Barker, B., Grandgenett, N. & Adamchuk, V. I. (2010). Impact of

robotics and geospatial technology interventions on youth STEM learning and

attitudes. *Journal of Research On Technology In Education (International*

Society For Technology In Education), 42(4), 391-408.

Ontario Ministry of Education. (2005). *The Ontario Curriculum, Grades 1 - 8:*

Mathematics. Retrieved from

<http://www.edu.gov.on.ca/eng/curriculum/elementary/math18curr.pdf>

Ontario Ministry of Education. (2006). *A Guide to effective instruction in*

mathematics, Kindergarten to Grade 6: Foundations of mathematics

instruction. Retrieved from

http://eworkshop.on.ca/edu/resources/guides/Guide_Math_K_6_Volume_1.pdf

f

Ontario Ministry of Education. (2011). *Paying attention to mathematics education:*

Seven foundational principles for improvement in mathematics, K–12.

Retrieved from

[http://www.edugains.ca/resourcesLNS/MathematicsFoundationalPrinciples/Se-](http://www.edugains.ca/resourcesLNS/MathematicsFoundationalPrinciples/SevenFoundationalPrinciples.pdf)

[venFoundationalPrinciples.pdf](http://www.edugains.ca/resourcesLNS/MathematicsFoundationalPrinciples/SevenFoundationalPrinciples.pdf)

- *Parkhurst, J., Skinner, C. H., Yaw, J., Poncy, B., Adcock, W. & Luna, E. (2010). Efficient class-wide remediation: Using technology to identify idiosyncratic math facts for additional automaticity drills. *International Journal of Behavioral Consultation & Therapy*, 6(2), 111-123.
- *Plass, J. L., Homer, B. D., Case, J., O'Keefe, P. A., Hayward, E. O., Stein, M. & Pedin, K. (2013). The Impact of individual, competitive, and collaborative mathematics game play on learning, performance, and motivation. *Journal of Educational Psychology*, 105(4), 1050-1066. doi:10.1037/a0032688
- *Polly, D. (2014). Elementary school teachers' use of technology during mathematics teaching. *Computers in The Schools*, 31(4), 271-292.
doi:10.1080/07380569.2014.969079
- Puentadura, R. (2014). *Frameworks for educational technology: SAMR, the EdTech Quintet, and the Horizon Report*. Retrieved from
www.hippasus.com/rrpweblog/archives/2014/04/27/FrameworksForEducationalTechnology_SAMRAndTheEdTechQuintet_CAIS.pdf
- Romrell, D., Kidder, L. C. & Wood, E. (2014). The SAMR model as a framework for evaluating mLearning. *Journal of Asynchronous Learning Network*, 18(2), 1–16.
- *Roschelle, J., Rafanan, K., Bhanot, R., Estrella, G., Penuel, B., Nussbaum, M. & Claro, S. (2010). Scaffolding group explanation and feedback with handheld technology: impact on students' mathematics learning. *Educational Technology Research & Development*, 58(4), 399-419. doi:10.1007/s11423-009-9142-9

- *Rosen, Y. & Beck-Hill, D. (2012). Intertwining digital content and a one-to-one laptop environment in teaching and learning: Lessons from the time to know program. *Journal of Research On Technology In Education*, 44(3), 225-241.
- Sailors, K. (2016, January 14). Apps are free for a reason: Learn to evaluate apps. Workshop presented at the Future of Educational Technology Conference, Orlando, Florida.
- *Schenke, K., Rutherford, T. & Farkas, G. (2014). Alignment of game design features and state mathematics standards: Do results reflect intentions?. *Computers & Education*, 76, 215-224. doi:10.1016/j.compedu.2014.03.019
- Schibeci, R., Lake, D., Phillips, R., Lowe, K., Cummings, R. & Miller, E. (2008). Evaluating the use of learning objects in Australian and New Zealand schools. *Computers & Education*, 50(1), 271–283.
<http://doi.org/10.1016/j.compedu.2006.05.006>
- *Skryabin, M., Zhang, J., Liu, L. & Zhang, D. (2015). How the ICT development level and usage influence student achievement in reading, mathematics, and science. *Computers & Education*, 85, 49-58.
doi:10.1016/j.compedu.2015.02.004
- Small, M. (2012). *Making Math Meaningful to Canadian Students, K - 8*, Second Edition. Toronto, Ontario: Nelson Education Ltd.
- Squires, D. & Preece, J. (1999). Predicting quality in educational software: Evaluating for learning, usability and the synergy between them. *Interacting with Computers*, 11(5), 467–483. [http://doi.org/10.1016/S0953-5438\(98\)00063-0](http://doi.org/10.1016/S0953-5438(98)00063-0)

- *Suppes, P., Liang, T., Macken, E. E. & Flickinger, D. P. (2014). Positive technological and negative pre-test-score effects in a four-year assessment of low socioeconomic status K-8 student learning in computer-based math and language arts courses. *Computers & Education*, 71, 23-32.
doi:10.1016/j.compedu.2013.09.008
- Tamim, R., Robert, B. & Richard, S. (2011). What forty years of research says about the impact of technology on learning: A Second-order meta-analysis and validation study. *Review of Educational Research*, 81(1), 4–28.
- *Tatar, E., Akkaya, A. & Kağızmanlı, T. B. (2014). Using dynamic software in mathematics: the case of reflection symmetry. *International Journal of Mathematical Education In Science & Technology*, 45(7), 980-995.
doi:10.1080/0020739X.2014.902129
- *ter Vrugte, J., de Jong, T., Vandercruysse, S., Wouters, P., van Oostendorp, H. & Elen, J. (2015). How competition and heterogeneous collaboration interact in prevocational game-based mathematics education. *Computers & Education*, 89, 42-52. doi:10.1016/j.compedu.2015.08.010
- *ter Vrugte, J., de Jong, T., Wouters, P., Vandercruysse, S., Elen, J. & van Oostendorp, H. (2015). When a game supports prevocational math education but integrated reflection does not. *Journal of Computer Assisted Learning*, 31(5), 462–480. <http://doi.org/10.1111/jcal.12104>
- Thomas, M. O. J. & Hong, Y. Y. (2012). Teacher integration of technology into mathematics learning. *International Journal for Technology in Mathematics Education*, 20(2), 69–84.

- *Torff, B. & Tirotta, R. (2010). Interactive whiteboards produce small gains in elementary students' self-reported motivation in mathematics. *Computers & Education*, 54(2), 379-383. doi:10.1016/j.compedu.2009.08.019
- Toronto District School Board (2015). *Base school and small school allocation*. Retrieved from <http://www.tdsb.on.ca/AboutUs/BusinessServices/BudgetsandFinancialStatements/SchoolBudgetAllocations.aspx>
- Trowler, V. (2010). *Student engagement literature review*. Heslington, York: The Higher Education Academy.
- *Tsuei, M. (2012). Using synchronous peer tutoring system to promote elementary students' learning in mathematics. *Computers & Education*, 58(4), 1171-1182. doi:10.1016/j.compedu.2011.11.025
- *Tsuei, M. (2014). Mathematics synchronous peer tutoring system for students with learning disabilities. *Educational Technology and Society*, 17(1), 115–127.
- *Vesel, J. & Robillard, T. (2013). Teaching mathematics vocabulary with an interactive signing math dictionary. *Journal of Research On Technology In Education (International Society For Technology In Education)*, 45(4), 361-389.
- Wiggins, G.P. & McTighe, J. (2006). *Understanding by design*. Upper Saddle River, NJ.: Person/Merrill/Prentice Hall.
- *Yang, D. C. & Tsai, Y. F. (2010). Promoting sixth graders' number sense and learning attitudes via technology-based environment. *Educational Technology and Society*, 13(4), 112–125.

- *Yang, D. & Li, M. (2013). Assessment of animated self-directed learning activities modules for children's number sense development. *Educational Technology & Society*, 16(3), 44–58.
- *Yang, K. (2014). The WebQuest model effects on mathematics curriculum learning in elementary school students. *Computers & Education*, 72, 158-166.
doi:10.1016/j.compedu.2013.11.006
- *Yang, Y., Zhang, L., Zeng, J., Pang, X., Lai, F. & Rozelle, S. (2013). Computers and the academic performance of elementary school-aged girls in China's poor communities. *Computers & Education*, 60(1), 335-346.
doi:10.1016/j.compedu.2012.08.011
- Zepke, N. & Leach, L. (2010). Improving student engagement: Ten proposals for action. *Active Learning in Higher Education*, 11(3), 167–177.
<http://doi.org/10.1177/1469787410379680>
- *Zhang, M. (2015). Understanding the relationships between interest in online math games and academic performance. *Journal of Computer Assisted Learning*, 31(3), 254-267. doi:10.1111/jcal.12077
- *Zydney, J. M., Bathke, A. & Hasselbring, T. S. (2014). Finding the optimal guidance for enhancing anchored instruction. *Interactive Learning Environments*, 22(5), 668-683. doi:10.1080/10494820.2012.745436

Appendix A

Results of the Inclusion and Exclusion Process

The results of the inclusion and exclusion process can be found by going to the following link. <http://goo.gl/I7nyQ7>

Appendix B

Studies Excluded from the Integration Analysis

| Number | Article | Reason |
|--------|---|---|
| 1 | Ball, C., Huang, K., Cotten, S. R., Rikard, R. & Coleman, L. O. (2016). Invaluable values: An Expectancy-value theory analysis of youths' academic motivations and intentions. <i>Information, Communication & Society</i> , 19(5), 618-638. doi:10.1080/1369118X.2016.1139616 | This study does not provide enough information about the program to determine the qualities of integration. It provides examples of programs that the teachers explored during professional development, but not how teachers used these tools in the classroom. In fact, Ball et al. (2016) report that "...we are unable to conclude if the decline was a result of the computing intervention" (p. 630). |
| 2 | Carr, J. M. (2012). Does math achievement h'APP'en when iPads and game-based learning are incorporated into fifth-grade mathematics instruction?. <i>Journal Of Information Technology Education</i> , 11, 269-286. | This study does not provide enough information about how the iPads were used in the classroom. The amount of time the iPad was used is reported, but there is no information on the types of activities used or how the iPads were integrated into classroom routines. |
| 3 | Carrasco, M. R. & Torrecilla, F. J. M. (2012). Learning environments with technological resources: A Look at their contribution to student performance in Latin American elementary schools. <i>Educational Technology Research and Development</i> , 60(6), 1107–1128. http://doi.org/10.1007/s11423-012-9262-5 | This study does not provide enough information about how the computer is used. The study records whether or not the student has access to a computer at home and at school, but not how the computer is used. |

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| 4 | House, J. D. & Telese, J. A. (2011). Effects of computer activities and classroom lesson strategies on motivation for mathematics learning for eighth-grade students in the United States and Korea. <i>International Journal Of Instructional Media</i> , 38(3), 295-306. | This study does not provide enough information about how the computer was used. The study records how often students use a computer in school and whether or not they play games or use the internet outside of school, but with no additional information on how the computer was integrated. |
| 5 | House, J. D. & Telese, J. A. (2012). Effects of mathematics lesson activities and computer use on algebra achievement of eighth-grade students in the United States and Japan: Findings from the TIMMS 2007 Assessment. <i>International Journal Of Instructional Media</i> , 39(1), 69-81. | This study does not provide enough information about how the computer was used. The study records whether or not students use a computer at home, school, or in their community, how frequently they use the computer to do homework, and if they play games or use the internet outside of school, but with no additional information on how the computer was integrated. |
| 6 | Jang, S. & Tsai, M. (2012). Exploring the TPACK of Taiwanese elementary mathematics and science teachers with respect to use of interactive whiteboards. <i>Computers & Education</i> , 59(2), 327-338. doi:10.1016/j.compedu.2012.02.003 | This study does not provide enough information about how the interactive white board (IWB) was used. The study recorded whether it was used in the classroom or not and the teacher's Technological Pedagogical and Content Knowledge, but no additional information on how the IWBs were used was provided. |
| 7 | Kiriakidis, P. P. & Geer, B. T. (2014). The Effect of success maker software on state scores in elementary school math. <i>Romanian Journal For Multidimensional Education / Revista Romaneasca Pentru Educatie Multidimensionala</i> , 6(2), 127-138. | This study does not provide enough information about how Success Maker was used within the classroom. The study reports on students' scores before and after their school used Success Maker for the year, but no information on how the program was used was provided. |

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| 8 | Li, Q. & Ma, X. (2010). A Meta-analysis of the effects of computer technology on school students' mathematics learning. <i>Educational Psychology Review</i> , 22(3), 215–243. http://doi.org/10.1007/s10648-010-9125-8 | This study does not provide enough information about how computer technology was used. The study found that a constructivist teaching approach with technology was the most beneficial describing the constructivist approach as, “student-centered instruction that emphasizes strategies such as discovery-based (inquiry-oriented) learning, problem-based (application-oriented) learning, and situated cognition based on constructivism” (Li et al., 2010, p. 219), but does not go into detail as to how this related to the use of technology. |
| 9 | Schenke, K., Rutherford, T. & Farkas, G. (2014). Alignment of game design features and state mathematics standards: Do results reflect intentions?. <i>Computers & Education</i> , 76, 215-224. doi:10.1016/j.compedu.2014.03.019 | This study does not provide enough information about how ST math was used. It reports that the students use the tool at their own pace and that ST Math was implemented for one year, but no additional information on how ST Math was used in the classroom was provided. |
| 10 | Skryabin, M., Zhang, J., Liu, L. & Zhang, D. (2015). How the ICT development level and usage influence student achievement in reading, mathematics, and science. <i>Computers & Education</i> , 85, 49-58. doi:10.1016/j.compedu.2015.02.004 | This study does not provide enough information on how ICT was used. The study reports on whether students use ICT at home and at school, but no additional information on how the ICT is used was provided. |
| 11 | Torff, B. & Tirotta, R. (2010). Interactive whiteboards produce small gains in elementary students' self-reported motivation in mathematics. <i>Computers & Education</i> , 54(2), 379-383. doi:10.1016/j.compedu.2009.08.019 | This study does not provide enough information on how the interactive white boards (IWBs) were used. The study reported on the frequency of use, but no additional information on how the IWB was used was provided. |
| 12 | Zhang, M. (2015). Understanding the relationships between interest in online math games and academic performance. <i>Journal Of Computer Assisted Learning</i> , 31(3), 254-267. doi:10.1111/jcal.12077 | This study does not provide enough information on how the game site was used. The study reported the frequency of use, but no additional information on how the site was used was provided. |

Appendix C

Studies Excluded from the Functionality Analysis

| Number | Article | Reason |
|--------|---|---|
| 1 | Cakir, O. & Simsek, N. (2010). A Comparative analysis of the effects of computer and paper-based personalization on student achievement. <i>Computers & Education</i> , 55(4), 1524-1531. doi:10.1016/j.compedu.2010.06.018 | This study does not provide enough information on the type of tool used. The study reports that personal computers were used and mentions that information was given via a webpage, but no additional information on the characteristics of the digital tool were provided. |
| 2 | Carr, J. M. (2012). Does math achievement h'APP'en when iPads and game-based learning are incorporated into fifth-grade mathematics instruction?. <i>Journal Of Information Technology Education</i> , 11, 269-286. | This study does not provide enough information on the type of tool used. The study reports that iPads with game-based applications were used, but no additional information on the characteristics of the games was provided. |
| 3 | Carrasco, M. R. & Torrecilla, F. J. M. (2012). Learning environments with technological resources: A look at their contribution to student performance in Latin American elementary schools. <i>Educational Technology Research and Development</i> , 60(6), 1107–1128. http://doi.org/10.1007/s11423-012-9262-5 | This study does not provide enough information on the type of tool used. The study is examining the use of computers, but no additional information on type of tools used. |
| 4 | House J. D. & Telese, J. A. (2011). Effects of computer activities and classroom lesson strategies on motivation for mathematics learning for eighth-grade students in the United States and Korea. <i>International Journal Of Instructional Media</i> , 38(3), 295-306. | This study does not provide enough information on the type of tool used. The study is examining the use of computers, but no additional information on type of tools used. |
| 5 | House, J. D. & Telese, J. A. (2012). Effects of mathematics lesson activities and computer use on algebra achievement of eighth-grade students in the United States and Japan: Findings from the TIMSS 2007 Assessment. <i>International Journal Of Instructional Media</i> , 39(1), 69-81. | This study does not provide enough information on the type of tool used. The study is examining the use of computers, but no additional information on type of tools used. |

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| 6 | Kiriakidis, P. P. & Geer, B. T. (2014). The Effect of success maker software on state scores in elementary school math. <i>Romanian Journal For Multidimensional Education / Revista Romaneasca Pentru Educatie Multidimensionala</i> , 6(2), 127-138. | This study does not provide enough information on the type of tool used. The study examines the impact of a software program called Success Maker, but no additional information on the program was provided. |
| 7 | Kiriakidis, P. P. & Johnson, T. (2015). Program evaluation: Integration of educational software into the elementary school math curriculum. <i>Romanian Journal For Multidimensional Education / Revista Romaneasca Pentru Educatie Multidimensionala</i> , 7(2), 55-65. doi:10.18662/rrem/2015.0702.05 | This study does not provide enough information on the type of tool used. The study examines the impact of a software program called Success Maker, but no additional information on the program was provided. |
| 8 | Skryabin, M., Zhang, J., Liu, L. & Zhang, D. (2015). How the ICT development level and usage influence student achievement in reading, mathematics, and science. <i>Computers & Education</i> , 85, 49-58. doi:10.1016/j.compedu.2015.02.004 | This study does not provide enough information on the type of tool used. The study examines the impact of Information and communication technologies (ICT), but no additional information on type of ICT was provided. |
| 9 | Tatar, E., Akkaya, A. & Kağızmanlı, T. B. (2014). Using dynamic software in mathematics: The Case of reflection symmetry. <i>International Journal Of Mathematical Education In Science & Technology</i> , 45(7), 980-995. doi:10.1080/0020739X.2014.902129 | This study does not provide enough information on the type of tool used. The study mentions GeoGebra, but no additional information on the functionality of the tool was provided. |
| 10 | Torff, B. & Tirotta, R. (2010). Interactive whiteboards produce small gains in elementary students' self-reported motivation in mathematics. <i>Computers & Education</i> , 54(2), 379-383. doi:10.1016/j.compedu.2009.08.019 | This study does not provide enough information on the type of tool used. The study mentions interactive white boards (IWBs), but no additional information on the functionality of the tool was provided. |
| 11 | Zhang, M. (2015). Understanding the relationships between interest in online math games and academic performance. <i>Journal Of Computer Assisted Learning</i> , 31(3), 254-267. doi:10.1111/jcal.12077 | This study does not provide enough information on the type of tool used. The study mentions math games but no additional information on the type of game was provided. |

Appendix D

Meta-Analysis Results

The results of the meta-analysis can be found by going to the following link.

<https://goo.gl/d2ketk>